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SCIENCE

HUXLEY'S
LECTURES AND LAY SERMONS
WITH AN INTRODUCTION BY
SIR OLIVER LODGE

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LECTURES & LAY SERMONS BY THOMAS HUXLEY

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INTRODUCTION

"It has been fortunate for the intellectual interest of life that the peace-loving Darwin and the self-effacing Wallace should have had a coadjutor more vividly touched with earthly fire, like the mortal charger who, champing more fiercely in the battle's fray, kept pace with the two undying steeds of Achilles. But we must remember that Professor Huxley's trenchant polemic has cast a kind of glory about the mere fact of man's ignorance which cannot possibly be kept up for long. Battles there will always be; but never again, perhaps, such a plunging through half-armed foemen, such an ἀριστεία of the Agnostic [such a record of individual triumphant feats], as we associate with that brilliant name."

F. W. H. Myers (Essay on "Charles Darwin and Agnosticism.")

Yes, battles there will always be, and Huxley was a splendid fighter, but the ostensible cause for which he fought—insistence on our present ignorance and on the folly of pretending to know what in truth we do not—is not a cause of satisfying fullness.

Ignorance it is right to confess, but it is never a thing to glory in. Only in an age in which rash assertion and mistaken tradition dominated thought too strongly was the flag of the Agnostic a conquering and triumphant emblem.

The battle has already shifted to other grounds; and before the end of his life Huxley realised that a great part of his warfare on the negative side was accomplished, and that it remained to restrain his camp-followers from prowling too savagely among the dead and wounded.

The essential and permanent aspect of his teaching, like the teaching of all men of science, lies on the positive side; and here effort is still necessary, for, though a great deal has been accomplished, the scientific training and interest of the average educated man is still lamentably deficient. Nor are the attempts to remedy the deficiency, as carried out in schools and colleges, always of the wisest and happiest kind. Nevertheless an effort is being made; and when things have settled down into their due proportion, future generations will recognise how much they owe to the preachings and teachings, the lay sermons and lectures, of Huxley.

The supremacy of truth, the reality of things, the cultiva-

tion of the senses, the need for realistic education and understanding of the physical universe in the midst of which man is set, the folly of yielding to mere glamour, and the sin of sophisticating what we can perceive of truth by hope of reward or dread of consequence—all this he strenuously fought for; and surely we may say that on the whole he won. No recognised branch of natural knowledge is now excluded from contemplation by reasonable men, nor is stringent inquiry cursed or dreaded, even by those to whose general purview it appeared at one time to be alien. The universe is recognised as one; and loyal allegiance must be accorded to every proven fact.

The battle is now transferred from this general contention to a more special one:—What range of facts can we admit into the category of positive knowledge? How much wider can we make the area of rational contemplation? Shall the human race be for ever limited to the domain of ether and atoms alone—as W. K. Clifford imagined—or are there other existences, just as real, just as important, just as well worthy of study, just as deserving of scrutiny by scientific methods?

It was no attack on Religion that Huxley led, it was an attack on the *præjudicia* of religion—the bland assumptions which did duty for reasoning, the self-interested arguments which concentrated attention on the past, attempted to despise the present, and held out illusory hopes for the future.

Study the universe before you, the living universe, with its traditions and history incorporated in it; cease to limit yourselves to the fancies and speculations of more ignorant times: that was Huxley's message.

A piece of chalk, he said, rightly interpreted, will tell you more about the physical history of the world than myriads of books. Try and learn the language of the chalk—"it is easier than Latin," so he said; and whoso knows the true history of a bit of chalk in a carpenter's pocket "is likely, if he will think his knowledge out to its ultimate results, to have a truer, and therefore a better, conception of this wonderful universe, and of man's relation to it, than the most learned student who is deep-read in the records of humanity and ignorant of those of nature."

This is language appropriate to intellectual warfare. It is part of his battle cry, it is an emphatic statement of one side of the truth, it is not the whole truth. Its comparative side

is its weak side: it is not really necessary to decry other forms of learning in order to exalt one—and Huxley showed later that he did not think so; it was only because one side was being neglected, and the other was in possession of the field, that he stood up manfully for the outcast, and dragged it into a prominent position.

The comparative side of his utterance was pugnacious, and therefore temporary, but the positive side is eternally true. Every bit of chalk *is* related to all the rest of the universe; and he who would know all about it—the life of the creatures whose remains compose it, its past, present, and future in all its phases—must have a grasp of the universe beyond the present scope of man. Tennyson said the same thing, more poetically, in his "Flower in the crannied wall."

But granting all this, what then? Because we are not to jump to conclusions too rapidly, because we must make our bearings and foundations sure, because our hopes and predictions must be well founded—is there to be no future, no hope for the human race? Is the end of all human struggle and effort to coincide with the probable end of the solar system — a dark, dead, lifeless lump careering through the depths of space? That were to reason too curiously to reason so.

Darwin could not contemplate such an ending—his instinct rebelled against it. In a notable passage he expresses the placid disbelief of an open-eyed investigator in such a conclusion—an investigator to whom the avenues of knowledge were in this direction closed, and who therefore would make no assertion one way or the other, but who instinctively felt that there must be some other answer. This he says:—

"Believing as I do that man in the distant future will be a far more perfect creature than he now is, it is an intolerable thought that he and all other sentient beings are doomed to complete annihilation after such long-continued slow progress."

And Tennyson, in his poem "Despair," has dramatically and impersonally voiced a violent development of the same feeling:—

"Why should we bear with an hour of torture, a moment of pain,
If every man die for ever, if all his griefs are in vain,
And the homeless planet at length will be wheel'd thro' the silence of space,
Motherless evermore of an ever-vanishing race,

When the worm shall have writhed its last, and its last brother-worm will
have fled
From the dead fossil skull that is left in the rocks of an earth that is
dead?"

And again in "Vastness"—

"What is it all, if we all of us end but in being our own corpse-coffins
at last,
Swallow'd in Vastness, lost in Silence, drown'd in the deeps of a meaning-
less Past?"

But in the fighting age such instincts and feelings and longings had rigorously to be suppressed. They were too perilously near the old bulwarks of superstition, which were to be broken down. Hence the side of assured positive knowledge was to be kept in the van—there was indeed plenty to do,—and a more comprehensive understanding of the puzzles of existence might wait until some positive knowledge began to appear, throwing the light of day upon them also.

While things remain in the dark they must be ignored. This is the basis of the Agnostic position. Flashes of speculation inevitably broke around it, and the hope was not lacking that "out of the molecular forces in a mutton chop Hamlet or Faust could be deduced by the physics of the future." But this enthusiastic and more than half-playful utterance of Tyndall (*Life and Letters of Huxley*, i. 231) is showing itself baseless—as baseless and as alien to the truly agnostic position as any of the superstitions that were then being attacked. Nevertheless, it is an interesting sign of the enthusiasm kindled by the physical discoveries of the nineteenth century—interesting and quite intelligible, and in its way legitimate,—for readers of the present day should learn where to emphasise, and where to discount, the utterances of the teachers of an enthusiastic and a fighting age.

Here, for instance, is the conclusion that Huxley draws from his piece of chalk, which, like lime exposed to the oxy-hydrogen flame, had become luminous under his scrutiny, so that "its clear rays, penetrating the abyss of the remote past, have brought within our ken some stages of the evolution of the earth. And in the shifting 'without haste but without rest' of the land and sea, as in the endless variation of the forms assumed by living beings, we have observed nothing but the natural product of the forces originally possessed by the substance of the universe."

Yes, that is a narrowly logical position. Keep rigidly to scrutiny of the material universe, and nothing beyond matter and force shall you discover. The conclusions that you draw will be entirely appropriate to the data. Things belonging to Cæsar will be rendered unto Cæsar. Of things not so belonging it need not yet be the time to discourse.

It would be a great mistake to assume that in all his contentions Huxley was right: we can imagine his sarcasm at the notion of infallibility in connection with his utterances. In a few cases he went, in my judgment, seriously wrong; and, led astray by controversial successes, he occasionally inflicted undeserved blows upon causes which had much of good in them and which might have flourished with his help,—upon such a cause as the early efforts at social work of the Salvation Army, for instance. And, by his concentrated insistence on the material side of things, he sometimes led his hearers to imagine that it was the only side that mattered, or even the only one that existed. Nevertheless it was not really against Religion that Huxley was wielding his battle-axe: it was against the Fetishism, the Polytheism, the Theism or Atheism and many other isms, with the relative merits and demerits of which, as he said, he had nothing to do:—" But this it is needful for my purpose to say, that if the religion of the present differs from that of the past, it is because the theology of the present has become more scientific than that of the past; because it has not only renounced idols of wood and idols of stone, but begins to see the necessity of breaking in pieces the idols built up of books and traditions and fine-spun ecclesiastical cobwebs: and of cherishing the noblest and most human of man's emotions, by worship 'for the most part of the silent sort' at the altar of the Unknown and Unknowable."

Here again we encounter a glorification of the Unknown God, which, as was implied before, cannot for ever, nor for long, be an object of rational worship. The intellectual business of the human race, and of scientific investigators, is to attack the Unknown and to make it, so far as possible, gradually known. Never completely known, nor at all adequately known, but never unknowable. Infinite things cannot be grasped by finite comprehension—in that sense unknowable, yes, but in no other. The universe itself is unknowable, in the sense of being infinite; but the human aspect of it is open to our examination and comprehension—with

that we have kinship and instinctive affinities—and it would only confuse the issue, and muddy the stream of scientific exploration, if we were to start on our quest with the idea that anything whatever was in any real and practical sense "unknowable."

To be able to ask a question is the first step towards getting an answer. There must be myriads of things in the universe about which it has never occurred to a human being to formulate any sort of idea. Those truly are outside our present ken; but anything of which we can discourse and think—that is on the way, by patience and perseverance and rigorous care and truthfulness, to become known.

The discourse of Huxley's on "A Liberal Education," which he gave to working men, is worthy of close attention, especially among the higher artizans who are determining to get for themselves, if so they can, and for their children still more, the advantages of some approach to a liberal education.

It is not the whole truth which he there expresses, it is one aspect of the truth—an aspect that then needed emphasis more than it does now. It is the view of an individual man, but of a profoundly wise and cultivated man, who would never wish us to limit our grasp of truth to an understanding of his own utterance, but would ask us to listen and progress further. What he is anxious about is that we shall not lag behind.

The metaphor of a game of chess is employed by Huxley as a parable of life:—

"The chess-board is the world, the pieces are the phenomena of the universe, the rules of the game are what we call the laws of nature. The player on the other side is hidden from us. We know that his play is always fair, just, and patient. . . . My metaphor will remind some of you of the famous picture in which Retzch has depicted Satan playing at chess with man for his soul. Substitute for the mocking fiend in that picture a calm, strong angel, who is playing 'for love,' as we say, and would rather lose than win, and I should accept it as an image of human life."

A little further on comes a passage, often quoted, about the strict discipline of physical nature:—

"Ignorance is visited as sharply as wilful disobedience —incapacity meets with the same punishment as crime.

Nature's discipline is not even a word and a blow, and the blow first; but the blow without the word. It is left to you to find out why your ears are boxed."

And presently comes that magnificent sentence about control of the passions, which I quote in order to draw to it special attention.

"That man, I think, has had a liberal education who has been so trained in youth that his body is the ready servant of his will, and does with ease and pleasure all the work that, as a mechanism, it is capable of; whose intellect is a clear, cold, logic engine, with all its parts of equal strength, and in smooth working order; ready, like a steam engine, to be turned to any kind of work, and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with a knowledge of the great and fundamental truths of nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions are trained to come to heel by a vigorous will, the servant of a tender conscience; who has learned to love all beauty, whether of nature or of art, to hate all vileness, and to respect others as himself.

"Such an one and no other, I conceive, has had a liberal education."

The petty Agnostics who, invoking the shade of Huxley, look out of their little holes and corners, peer through a foggy atmosphere, and deny the stars, have no support from their great precursor. He would counsel them to see life steadily and see it whole, and to remember that the greatest men are not those who blink difficulties and claim that they have done more than they have, but those who modestly admit every difficulty, and where they are ignorant conspicuously avow it.

To those, for instance, who imagine that Darwin discovered the whole truth about the origin of species, by his undoubtedly just emphasis on struggle for existence and survival of the fittest—since these influences tend to clinch and make permanent the variations which otherwise arise,—to those who imagine that we understand fully the origin of those variations, without which natural selection would have nothing to work upon, let us quote the following from page 103 of Huxley's controversial reply to foreign critics of Darwinism. It is an extract from an utterance of Darwin himself:—

"Our ignorance of the laws of variation is profound. Not in one case out of a hundred can we pretend to assign any

reason why this or that part varies more or less from the same part in the parents."

Lastly, in these days when women have come so much to the front, and are showing signs of occasionally even over-complete emancipation, it is well to remember that only half a century ago the cause of their rational and higher education had to be fought. Huxley's article on "Emancipation—Black and White," an outcome of the American Civil War, is a plea for giving a fair field and no favour.

"Emancipate girls," he says. "Let them, if they so please, become merchants, barristers, politicians. . . .

"Woman will be found to be fearfully weighted in the race of life. . . .

"The duty of man is to see that not a grain is piled upon that load beyond what nature imposes; that injustice is not added to inequality."

So, then, we come to the more technically scientific lectures, the biological teaching of which he was a master. He discusses, among other things, the probable origin of the human race—whether it spread from one centre or from many—and evidently inclines to the view that human evolution took place at only one point of the earth's surface, and was distributed over it by migration. But on this he does not dogmatise: the alternative views have difficulties of their own. The nascent stages of humanity must have been delicate and dangerous in the extreme, and it seems unlikely that the process of evolving man would be often repeated, at different places, on a planet. But then it is difficult to contemplate any form of uncivilised migration which from a centre in, say, Asia could reach and populate the American continent down to Patagonia.

"The whole tendency of modern science is to thrust the origination of things further and further into the background; and the chief philosophical objection to Adam [is], not his oneness, but the hypothesis of his special creation."

Most of this part of the present book consists of a course of lectures on the skull and its development. The various stages of the human skull, and of the animal skull, are dealt with, and their points of similarity and difference emphasised.

To any one who doubts the physical ancestry of man, as

part of the animal world, these chapters will bear the meaning which they are intended to convey.

But if any one at this time of day thinks that physical ancestry is the last word, and exhausts the meaning of human genesis and of what may be meant by "Adam,"—any one who thinks that Spirit and Genius and Inspiration offer no field for investigation, furnish no clue to interpretation, and are foreign to any rational study of the human race, the possibilities of which are exhausted by an exemplary scrutiny of dry bones—such an one would wrest the teachings of the learned among mankind and apply them to his own stultification.

It is not by denying and restricting that we progress, it is by examining the ground and advancing, without haste without rest, till we reach fresh woods and pastures new. Admitting those things which are behind, and reaching forward to those things that are before—that is the attitude of the genuine explorer of nature, for all time.

The truth of one set of things is quite compatible with the truth of many another set of things. Only let the truth in every age be established, and let no corner of the universe—physical, mental, moral, spiritual—be closed to patient and reverent investigation.

To those few unfaithful pastors who dare not admit the plain teachings of modern science, and to those many pathetic half-educated strivers after knowledge who think it their duty to deny everything else, I say:—

Oh, race of men, be worthy of thy heroes. Look not back on bones and lowly ancestors alone as exhausting the truth of the universe; learn the lessons these things can teach, and bethink yourself also of the triumphs of mind over matter; realise the dominion of music and poetry and science and art; and remember, when tempted to take a low and depressed view of humanity, that during our own days we have had living with us, on this small island, a Darwin, a Tennyson, and a Huxley.

OLIVER LODGE.

July 1910.

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CONTENTS

LECTURES AND LAY SERMONS

ON A PIECE OF CHALK

[1868]

If a well were sunk at our feet in the midst of the city of Norwich, the diggers would very soon find themselves at work in that white substance almost too soft to be called rock, with which we are all familiar as "chalk."

Not only here, but over the whole county of Norfolk, the well-sinker might carry his shaft down many hundred feet without coming to the end of the chalk; and, on the sea-coast, where the waves have pared away the face of the land which breasts them, the scarped faces of the high cliffs are often wholly formed of the same material. Northward, the chalk may be followed as far as Yorkshire; on the south coast it appears abruptly in the picturesque western bays of Dorset, and breaks into the Needles of the Isle of Wight; while on the shores of Kent it supplies that long line of white cliffs to which England owes her name of Albion.

Were the thin soil which covers it all washed away, a curved band of white chalk, here broader and there narrower, might be followed diagonally across England from Lulworth in Dorset, to Flamborough Head in Yorkshire—a distance of over 280 miles as the crow flies. From this band to the North Sea, on the east, and the Channel, on the south, the chalk is largely hidden by other deposits; but, except in the Weald of Kent and Sussex, it enters into the very foundation of all the south-eastern counties.

Attaining, as it does in some places, a thickness of more than a thousand feet, the English chalk must be admitted to be a mass of considerable magnitude. Nevertheless, it covers but an insignificant portion of the whole area occupied by the chalk formation of the globe, much of which has the same general characters as ours, and is found in detached patches, some less, and others more extensive, than the English.

Chalk occurs in north-west Ireland; it stretches over a large part of France—the chalk which underlies Paris being, in fact, a continuation of that of the London basin; it runs through Denmark and Central Europe, and extends southward to North Africa; while eastward, it appears in the Crimea and in Syria, and may be traced as far as the shores of the Sea of Aral, in Central Asia.

If all the points at which true chalk occurs were circumscribed, they would lie within an irregular oval about 3,000 miles in long diameter—the area of which would be as great as that of Europe, and would many times exceed that of the largest existing inland sea—the Mediterranean.

Thus the chalk is no unimportant element in the masonry of the earth's crust, and it impresses a peculiar stamp, varying with the conditions to which it is exposed, on the scenery of the districts in which it occurs. The undulating downs and rounded coombs, covered with sweet-grassed turf, of our inland chalk country, have a peacefully domestic and mutton-suggesting prettiness, but can hardly be called either grand or beautiful. But on our southern coasts, the wall-sided cliffs, many hundred feet high, with vast needles and pinnacles standing out in the sea, sharp and solitary enough to serve as perches for the wary cormorant, confer a wonderful beauty and grandeur upon the chalk headlands. And, in the East, chalk has its share in the formation of some of the most venerable of mountain ranges, such as the Lebanon.

What is this wide-spread component of the surface of the earth? and whence did it come?

You may think this no very hopeful inquiry. You may not unnaturally suppose that the attempt to solve such problems as these can lead to no result, save that of entangling the inquirer in vague speculations, incapable of refutation and of verification. If such were really the case, I should have selected some other subject than a "piece of chalk" for my discourse. But, in truth, after much deliberation, I have been unable to think of any topic which would so well enable me to lead you to see how solid is the foundation upon which some of the most startling conclusions of physical science rest.

A great chapter of the history of the world is written in the chalk. Few passages in the history of man can be supported by such an overwhelming mass of direct and indirect evidence as

that which testifies to the truth of the fragment of the history of the globe, which I hope to enable you to read, with your own eyes, to-night.

Let me add, that few chapters of human history have a more profound significance for ourselves. I weigh my words well when I assert, that the man who should know the true history of the bit of chalk which every carpenter carries about in his breeches-pocket, though ignorant of all other history, is likely, if he will think his knowledge out to its ultimate results, to have a truer, and therefore a better, conception of this wonderful universe, and of man's relation to it, than the most learned student who is deep-read in the records of humanity and ignorant of those of nature.

The language of the chalk is not hard to learn, not nearly so hard as Latin, if you only want to get at the broad features of the story it has to tell; and I propose that we now set to work to spell that story out together.

We all know that if we "burn" chalk the result is quicklime. Chalk, in fact, is a compound of carbonic acid gas and lime, and when you make it very hot the carbonic acid flies away and the lime is left.

By this method of procedure we see the lime, but we do not see the carbonic acid. If, on the other hand, you were to powder a little chalk and drop it into a good deal of strong vinegar, there would be a great bubbling and fizzing, and, finally, a clear liquid, in which no sign of chalk would appear. Here you see the carbonic acid in the bubbles; the lime, dissolved in the vinegar, vanishes from sight. There are a great many other ways of showing that chalk is essentially nothing but carbonic acid and quicklime. Chemists enunciate the result of all the experiments which prove this, by stating that chalk is almost wholly composed of "carbonate of lime."

It is desirable for us to start from the knowledge of this fact, though it may not seem to help us very far towards what we seek. For carbonate of lime is a widely-spread substance, and is met with under very various conditions. All sorts of limestones are composed of more or less pure carbonate of lime. The crust which is often deposited by waters which have drained through limestone rocks, in the form of what are called stalagmites and stalactites, is carbonate of lime. Or, to take a more familiar example, the fur on the inside of a tea-kettle is carbonate of lime; and, for anything chemistry tells us to the contrary, the

chalk might be a kind of gigantic fur upon the bottom of the earth-kettle, which is kept pretty hot below.

Let us try another method of making the chalk tell us its own history. To the unassisted eye chalk looks simply like a very loose and open kind of stone. But it is possible to grind a slice of chalk down so thin that you can see through it—until it is thin enough, in fact, to be examined with any magnifying power that may be thought desirable. A thin slice of the fur of a kettle might be made in the same way. If it were examined microscopically, it would show itself to be a more or less distinctly laminated mineral substance, and nothing more.

But the slice of chalk presents a totally different appearance when placed under the microscope. The general mass of it is made up of very minute granules; but, imbedded in this matrix, are innumerable bodies, some smaller and some larger, but, on a rough average, not more than a hundredth of an inch in diameter, having a well-defined shape and structure. A cubic inch of some specimens of chalk may contain hundreds of thousands of these bodies, compacted together with incalculable millions of the granules.

The examination of a transparent slice gives a good notion of the manner in which the components of the chalk are arranged, and of their relative proportions. But, by rubbing up some chalk with a brush in water and then pouring off the milky fluid, so as to obtain sediments of different degrees of fineness, the granules and the minute rounded bodies may be pretty well separated from one another, and submitted to microscopic examination, either as opaque or as transparent objects. By combining the views obtained in these various methods, each of the rounded bodies may be proved to be a beautifully-constructed calcareous fabric, made up of a number of chambers, communicating freely with one another. The chambered bodies are of various forms. One of the commonest is something like a badly-grown raspberry, being formed of a number of nearly globular chambers of different sizes congregated together. It is called *Globigerina*, and some specimens of chalk consist of little else than *Globigerinæ* and granules.

Let us fix our attention upon the *Globigerina*. It is the spoor of the game we are tracking. If we can learn what it is and what are the conditions of its existence, we shall see our way to the origin and past history of the chalk.

A suggestion which may naturally enough present itself is,

that these curious bodies are the result of some process of aggregation which has taken place in the carbonate of lime; that, just as in winter, the rime on our windows simulates the most delicate and elegantly arborescent foliage—proving that the mere mineral, water, may, under certain conditions, assume the outward form of organic bodies—so this mineral substance, carbonate of lime, hidden away in the bowels of the earth, has taken the shape of these chambered bodies. I am not raising a merely fanciful and unreal objection. Very learned men, in former days, have even entertained the notion that all the formed things found in rocks are of this nature; and if no such conception is at present held to be admissible, it is because long and varied experience has now shown that mineral matter never does assume the form and structure we find in fossils. If any one were to try to persuade you that an oyster-shell (which is also chiefly composed of carbonate of lime) had crystallised out of sea-water, I suppose you would laugh at the absurdity. Your laughter would be justified by the fact that all experience tends to show that oyster-shells are formed by the agency of oysters, and in no other way. And if there were no better reasons, we should be justified, on like grounds, in believing that *Globigerina* is not the product of anything but vital activity.

Happily, however, better evidence in proof of the organic nature of the *Globigerinæ* than that of analogy is forthcoming. It so happens that calcareous skeletons, exactly similar to the *Globigerinæ* of the chalk, are being formed, at the present moment, by minute living creatures, which flourish in multitudes, literally more numerous than the sands of the sea-shore, over a large extent of that part of the earth's surface which is covered by the ocean.

The history of the discovery of these living *Globigerinæ*, and of the part which they play in rock building, is singular enough. It is a discovery which, like others of no less scientific importance, has arisen, incidentally, out of work devoted to very different and exceedingly practical interests.

When men first took to the sea, they speedily learned to look out for shoals and rocks; and the more the burthen of their ships increased, the more imperatively necessary it became for sailors to ascertain with precision the depth of the waters they traversed. Out of this necessity grew the use of the lead and sounding line; and, ultimately, marine-surveying, which is the recording of the

form of coasts and of the depth of the sea, as ascertained by the sounding-lead, upon charts.

At the same time, it became desirable to ascertain and to indicate the nature of the sea-bottom, since this circumstance greatly affects its goodness as holding ground for anchors. Some ingenious tar, whose name deserves a better fate than the oblivion into which it has fallen, attained this object by "arming" the bottom of the lead with a lump of grease, to which more or less of the sand or mud, or broken shells, as the case might be, adhered, and was brought to the surface. But, however well adapted such an apparatus might be for rough nautical purposes, scientific accuracy could not be expected from the armed lead, and to remedy its defects (especially when applied to sounding in great depths) Lieut. Brooke, of the American Navy, some years ago invented a most ingenious machine, by which a considerable portion of the superficial layer of the sea-bottom can be scooped out and brought up from any depth to which the lead descends.

In 1853, Lieut. Brooke obtained mud from the bottom of the North Atlantic, between Newfoundland and the Azores, at a depth of more than 10,000 feet, or two miles, by the help of this sounding apparatus. The specimens were sent for examination to Ehrenberg of Berlin, and to Bailey of West Point, and those able microscopists found that this deep-sea mud was almost entirely composed of the skeletons of living organisms — the greater proportion of these being just like the *Globigerinæ* already known to occur in the chalk.

Thus far, the work had been carried on simply in the interests of science, but Lieut. Brooke's method of sou ding acquired a high commercial value, when the enterprise of laying down the telegraph-cable between this country and the United States was undertaken. For it became a matter of immense importance to know, not only the depth of the sea over the whole line along which the cable was to be laid, but the exact nature of the bottom, so as to guard against chances of cutting or fraying the strands of that costly rope. The Admiralty consequently ordered Captain Dayman, an old friend and shipmate of mine, to ascertain the depth over the whole line of the able, and to bring back specimens of the bottom. In former days, such a command as this might have sounded very much like one of the impossible things which the young prince in the Fairy Tales is ordered to do before he can obtain the hand of the princess.

However, in the months of June and July, 1857, my friend performed the task assigned to him with great expedition and precision, without, so far as I know, having met with any reward of that kind. The specimens of Atlantic mud which he procured were sent to me to be examined and reported upon.[1]

The result of all these operations is, that we know the contours and the nature of the surface-soil covered by the North Atlantic for a distance of 1,700 miles from east to west, as well as we know that of any part of the dry land.

It is a prodigious plain—one of the widest and most even plains in the world. If the sea were drained off, you might drive a waggon all the way from Valentia, on the west coast of Ireland, to Trinity Bay, in Newfoundland. And, except upon one sharp incline about 200 miles from Valentia, I am not quite sure that it would even be necessary to put the skid on, so gentle are the ascents and descents upon that long route. From Valentia the road would lie down-hill for about 200 miles to the point at which the bottom is now covered by 1,700 fathoms of sea-water. Then would come the central plain, more than a thousand miles wide, the inequalities of the surface of which would be hardly perceptible, though the depth of water upon it now varies from 10,000 to 15,000 feet; and there are places in which Mont Blanc might be sunk without showing its peak above water. Beyond this, the ascent on the American side commences, and gradually leads, for about 300 miles, to the Newfoundland shore.

Almost the whole of the bottom of this central plain (which extends for many hundred miles in a north and south direction) is covered by a fine mud, which, when brought to the surface, dries into a greyish-white friable substance. You can write with this on a blackboard, if you are so inclined; and, to the eye, it is quite like very soft, greyish chalk. Examined chemically, it proves to be composed almost wholly of carbonate of lime; and if you make a section of it, in the same way as that of the piece of chalk was made, and view it with the microscope, it presents innumerable *Globigerinæ* embedded in a granular matrix.

Thus this deep-sea mud is substantially chalk. I say sub-

[1] See Appendix to Captain Dayman's "Deep-sea Soundings in the North Atlantic Ocean between Ireland and Newfoundland, made in H.M.S. *Cyclops*." Published by order of the Lords Commissioners of the Admiralty, 1858. They have since formed the subject of an elaborate Memoir by Messrs. Parker and Jones, published in the "Philosophical Transactions" for 1865.

stantially, because there are a good many minor differences; but as these have no bearing on the question immediately before us,—which is the nature of the *Globigerinæ* of the chalk,—it is unnecessary to speak of them.

Globigerinæ of every size, from the smallest to the largest, are associated together in the Atlantic mud, and the chambers of many are filled by a soft animal matter. This soft substance is, in fact, the remains of the creature to which the *Globigerina* shell, or rather skeleton, owes its existence—and which is an animal of the simplest imaginable description. It is, in fact, a mere particle of living jelly, without defined parts of any kind—without a mouth, nerves, muscles, or distinct organs, and only manifesting its vitality to ordinary observation by thrusting out and retracting from all parts of its surface, long filamentous processes, which serve for arms and legs. Yet this amorphous particle, devoid of everything which in the higher animals we call organs, is capable of feeding, growing, and multiplying; of separating from the ocean the small proportion of carbonate of lime which is dissolved in sea-water; and of building up that substance into a skeleton for itself, according to a pattern which can be imitated by no other known agency.

The notion that animals can live and flourish in the sea, at the vast depths from which apparently living *Globigerinæ* have been brought up, does not agree very well with our usual conceptions respecting the conditions of animal life; and it is not so absolutely impossible as it might at first sight appear to be, that the *Globigerinæ* of the Atlantic sea-bottom do not live and die where they are found.

As I have mentioned, the soundings from the great Atlantic plain are almost entirely made up of *Globigerinæ*, with the granules which have been mentioned and some few other calcareous shells; but a small percentage of the chalky mud—perhaps at most some five per cent. of it—is of a different nature, and consists of shells and skeletons composed of silex, or pure flint. These silicious bodies belong partly to the lowly vegetable organisms which are called *Diatomaceæ*, and partly to the minute, and extremely simple, animals, termed *Radiolariæ*. It is quite certain that these creatures do not live at the bottom of the ocean, but at its surface—where they may be obtained in prodigious numbers by the use of a properly constructed net. Hence it follows that these silicious organisms, though they are not heavier than the lightest dust, must have fallen, in some cases,

through fifteen thousand feet of water, before they reached their final resting-place on the ocean floor. And, considering how large a surface these bodies expose in proportion to their weight, it is probable that they occupy a great length of time in making their burial journey from the surface of the Atlantic to the bottom.

But if the *Radiolariæ* and Diatoms are thus rained upon the bottom of the sea, from the superficial layer of its waters in which they pass their lives, it is obviously possible that the *Globigerinæ* may be similarly derived; and if they were so, it would be much more easy to understand how they obtain their supply of food than it is at present. Nevertheless, the positive and negative evidence all points the other way. The skeletons of the full-grown, deep-sea *Globigerinæ* are so remarkably solid and heavy in proportion to their surface as to seem little fitted for floating; and, as a matter of fact, they are not to be found along with the Diatoms and *Radiolariæ* in the uppermost stratum of the open ocean.

It has been observed, again, that the abundance of *Globigerinæ*, in proportion to other organisms, of like kind, increases with the depth of the sea; and that deep-water *Globigerinæ* are larger than those which live in shallower parts of the sea; and such facts negative the supposition that these organisms have been swept by currents from the shallows into the deeps of the Atlantic.

It therefore seems to be hardly doubtful that these wonderful creatures live and die at the depths in which they are found.[1]

However, the important points for us are, that the living *Globigerinæ* are exclusively marine animals, the skeletons of which abound at the bottom of deep seas; and that there is not a shadow of reason for believing that the habits of the *Globigerinæ* of the chalk differed from those of the existing species. But if this be true, there is no escaping the conclusion that the chalk itself is the dried mud of an ancient deep sea.

[1] During the cruise of H.M.S. *Bull-dog*, commanded by Sir Leopold M'Clintock, in 1860, living star-fish were brought up, clinging to the lowest part of the sounding-line, from a depth of 1,260 fathoms, midway between Cape Farewell, in Greenland, and the Rockall banks. Dr. Wallich ascertained that the sea-bottom at this point consisted of the ordinary *Globigerina* ooze, and that the stomachs of the star-fishes were full of *Globigerinæ*. This discovery removes all objections to the existence of living *Globigerinæ* at great depths, which are based upon the supposed difficulty of maintaining animal life under such conditions; and it throws the burden of proof upon those who object to the supposition that the *Globigerinæ* live and die where they are found.

In working over the soundings collected by Captain Dayman, I was surprised to find that many of what I have called the "granules" of that mud, were not, as one might have been tempted to think at first, the mere powder and waste of *Globigerinæ*, but that they had a definite form and size. I termed these bodies "*coccoliths*," and doubted their organic nature. Dr. Wallich verified my observation, and added the interesting discovery that, not unfrequently, bodies similar to these "coccoliths" were aggregated together into spheroids, which he termed "*coccospheres*." So far as we knew, these bodies, the nature of which is extremely puzzling and problematical, were peculiar to the Atlantic soundings.

But, a few years ago, Mr. Sorby, in making a careful examination of the chalk by means of thin sections and otherwise, observed, as Ehrenberg had done before him, that much of its granular basis possesses a definite form. Comparing these formed particles with those in the Atlantic soundings, he found the two to be identical; and thus proved that the chalk, like the surroundings, contains these mysterious coccoliths and coccospheres. Here was a further and most interesting confirmation, from internal evidence, of the essential identity of the chalk with modern deep-sea mud. *Globigerinæ*, coccoliths, and coccospheres are found as the chief constituents of both, and testify to the general similarity of the conditions under which both have been formed.[1]

The evidence furnished by the hewing, facing, and superposition of the stones of the Pyramids, that these structures were built by men, has no greater weight than the evidence that the chalk was built by *Globigerinæ;* and the belief that those ancient pyramid-builders were terrestrial and air-breathing creatures like ourselves, is not better based than the conviction that the chalk-makers lived in the sea.

But as our belief in the building of the Pyramids by men is not only grounded on the internal evidence afforded by these structures, but gathers strength from multitudinous collateral proofs, and is clinched by the total absence of any reason for a contrary belief; so the evidence drawn from the *Globigerinæ*

[1] I have recently traced out the development of the "coccoliths" from a diameter of $\frac{1}{7000}$th of an inch up to their largest size (which is about $\frac{1}{1600}$th), and no longer doubt that they are produced by independent organisms, which, like the *Globigerinæ*, live and die at the bottom of the sea.

that the chalk is an ancient sea-bottom, is fortified by innumerable independent lines of evidence; and our belief in the truth of the conclusion to which all positive testimony tends, receives the like negative justification from the fact that no other hypothesis has a shadow of foundation.

It may be worth while briefly to consider a few of these collateral proofs that the chalk was deposited at the bottom of the sea.

The great mass of the chalk is composed, as we have seen, of the skeletons of *Globigerinæ*, and other simple organisms, imbedded in granular matter. Here and there, however, this hardened mud of the ancient sea reveals the remains of higher animals which have lived and died, and left their hard parts in the mud, just as the oysters die and leave their shells behind them, in the mud of the present seas.

There are, at the present day, certain groups of animals which are never found in fresh waters, being unable to live anywhere but in the sea. Such are the corals; those corallines which are called *Polyzoa*; those creatures which fabricate the lamp-shells, and are called *Brachiopoda*; the pearly *Nautilus*, and all animals allied to it; and all the forms of sea-urchins and star-fishes.

Not only are all these creatures confined to salt water at the present day; but, so far as our records of the past go, the conditions of their existence have been the same: hence, their occurrence in any deposit is as strong evidence as can be obtained, that that deposit was formed in the sea. Now the remains of animals of all the kinds which have been enumerated, occur in the chalk, in greater or less abundance; while not one of those forms of shell-fish which are characteristic of fresh water has yet been observed in it.

When we consider that the remains of more than three thousand distinct species of aquatic animals have been discovered among the fossils of the chalk, that the great majority of them are of such forms as are now met with only in the sea, and that there is no reason to believe that any one of them inhabited fresh water—the collateral evidence that the chalk represents an ancient sea-bottom acquires as great force as the proof derived from the nature of the chalk itself. I think you will now allow that I did not overstate my case when I asserted that we have as strong grounds for believing that all the vast area of dry land, at present occupied by the chalk, was once at the bottom of the sea,

as we have for any matter of history whatever; while there is no justification for any other belief.

No less certain it is that the time during which the countries we now call south-east England, France, Germany, Poland, Russia, Egypt, Arabia, Syria, were more or less completely covered by a deep sea, was of considerable duration.

We have already seen that the chalk is, in places, more than a thousand feet thick. I think you will agree with me, that it must have taken some time for the skeletons of animalculæ of a hundredth of an inch in diameter to heap up such a mass as that. I have said that throughout the thickness of the chalk the remains of other animals are scattered. These remains are often in the most exquisite state of preservation. The valves of the shell-fishes are commonly adherent; the long spines of some of the sea-urchins, which would be detached by the smallest jar, often remain in their places. In a word, it is certain that these animals have lived and died when the place which they now occupy was the surface of as much of the chalk as had then been deposited; and that each has been covered up by the layer of *Globigerina* mud, upon which the creatures imbedded a little higher up have, in like manner, lived and died. But some of these remains prove the existence of reptiles of vast size in the chalk sea. These lived their time, and had their ancestors and descendants, which assuredly implies time, reptiles being of slow growth.

There is more curious evidence, again, that the process of covering up, or, in other words, the deposit of *Globigerina* skeletons, did not go on very fast. It is demonstrable that an animal of the cretaceous sea might die, that its skeleton might lie uncovered upon the sea-bottom long enough to lose all its outward coverings and appendages by putrefaction; and that, after this had happened, another animal might attach itself to the dead and naked skeleton, might grow to maturity, and might itself die before the calcareous mud had buried the whole.

Cases of this kind are admirably described by Sir Charles Lyell. He speaks of the frequency with which geologists find in the chalk a fossilised sea-urchin, to which is attached the lower valve of a *Crania*. This is a kind of shell-fish, with a shell composed of two pieces, of which, as in the oyster, one is fixed and the other free.

"The upper valve is almost invariably wanting, though occasionally found in a perfect state of preservation in the white

chalk at some distance. In this case, we see clearly that the sea-urchin first lived from youth to age, then died and lost its spines, which were carried away. Then the young *Crania* adhered to the bared shell, grew and perished in its turn; after which, the upper valve was separated from the lower, before the Echinus became enveloped in chalky mud." [1]

A specimen in the Museum of Practical Geology, in London, still further prolongs the period which must have elapsed between the death of the sea-urchin, and its burial by the *Globigerinæ*. For the outward face of the valve of a *Crania*, which is attached to a sea-urchin (*Micraster*), is itself overrun by an incrusting coralline, which spreads thence over more or less of the surface of the sea-urchin. It follows that, after the upper valve of the *Crania* fell off, the surface of the attached valve must have remained exposed long enough to allow of the growth of the whole coralline, since corallines do not live embedded in mud.

The progress of knowledge may one day enable us to deduce from such facts as these the maximum rate at which the chalk can have accumulated, and thus to arrive at the minimum duration of the chalk period. Suppose that the valve of the *Crania* upon which a coralline has fixed itself in the way just described, is so attached to the sea-urchin that no part of it is more than an inch above the face upon which the sea-urchin rests. Then, as the coralline could not have fixed itself, if the *Crania* had been covered up with chalk mud, and could not have lived had itself been so covered, it follows, that an inch of chalk mud could not have accumulated within the time between the death and decay of the soft parts of the sea-urchin and the growth of the coralline to the full size which it has attained. If the decay of the soft parts of the sea-urchin; the attachment, growth to maturity, and decay of the *Crania*; and the subsequent attachment and growth of the coralline, took a year (which is a low estimate enough), the accumulation of the inch of chalk must have taken more than a year: and the deposit of a thousand feet of chalk must, consequently, have taken more than twelve thousand years.

The foundation of all this calculation is, of course, a knowledge of the length of time the *Crania* and the coralline needed to attain their full size; and, on this head, precise knowledge is at present wanting. But there are circumstances which tend to show that nothing like an inch of chalk has accumulated during

[1] "Elements of Geology," by Sir Charles Lyell, Bart., F.R.S., p. 23.

the life of a *Crania;* and, on any probable estimate of the length of that life, the chalk period must have had a much longer duration than that thus roughly assigned to it.

Thus, not only is it certain that the chalk is the mud of an ancient sea-bottom; but it is no less certain, that the chalk sea existed during an extremely long period, though we may not be prepared to give a precise estimate of the length of that period in years. The relative duration is clear, though the absolute duration may not be definable. The attempt to affix any precise date to the period at which the chalk sea began, or ended, its existence, is baffled by difficulties of the same kind. But the relative age of the cretaceous epoch may be determined with as great ease and certainty as the long duration of that epoch.

You will have heard of the interesting discoveries recently made, in various parts of Western Europe, of flint implements, obviously worked into shape by human hands, under circumstances which show conclusively that man is a very ancient denizen of these regions.

It has been proved that the whole populations of Europe, whose existence has been revealed to us in this way, consisted of savages, such as the Esquimaux are now; that, in the country which is now France, they hunted the reindeer, and were familiar with the ways of the mammoth and the bison. The physical geography of France was in those days different from what it is now—the river Somme, for instance, having cut its bed a hundred feet deeper between that time and this; and, it is probable, that the climate was more like that of Canada or Siberia, than that of Western Europe.

The existence of these people is forgotten even in the traditions of the oldest historical nations. The name and fame of them had utterly vanished until a few years back; and the amount of physical change which has been effected since their day renders it more than probable that, venerable as are some of the historical nations, the workers of the chipped flints of Hoxne or of Amiens are to them, as they are to us, in point of antiquity.

But, if we assign to these hoar relics of long-vanished generations of men the greatest age that can possibly be claimed for them, they are not older than the drift, or boulder clay, which, in comparison with the chalk, is but a very juvenile deposit. You need go no further than your own sea-board for evidence of this fact. At one of the most charming spots on the coast of Norfolk,

Cromer, you will see the boulder clay forming a vast mass, which lies upon the chalk, and must consequently have come into existence after it. Huge boulders of chalk are, in fact, included in the clay, and have evidently been brought to the position they now occupy by the same agency as that which has planted blocks of syenite from Norway side by side with them.

The chalk, then, is certainly older than the boulder clay. If you ask how much, I will again take you no further than the same spot upon your own coasts for evidence. I have spoken of the boulder clay and drift as resting upon the chalk. That is not strictly true. Interposed between the chalk and the drift is a comparatively insignificant layer, containing vegetable matter. But that layer tells a wonderful history. It is full of stumps of trees standing as they grew. Fir-trees are there with their cones, and hazel-bushes with their nuts; there stand the stools of oak and yew trees, beeches and alders. Hence this stratum is appropriately called the "forest-bed."

It is obvious that the chalk must have been upheaved and converted into dry land, before the timber trees could grow upon it. As the bolls of some of these trees are from two to three feet in diameter, it is no less clear that the dry land thus formed remained in the same condition for long ages. And not only do the remains of stately oaks and well-grown firs testify to the duration of this condition of things, but additional evidence to the same effect is afforded by the abundant remains of elephants, rhinoceroses, hippopotamuses, and other great wild beasts, which it has yielded to the zealous search of such men as the Rev. Mr. Gunn.

When you look at such a collection as he has formed, and bethink you that these elephantine bones did veritably carry their owners about, and these great grinders crunch, in the dark woods of which the forest-bed is now the only trace, it is impossible not to feel that they are as good evidence of the lapse of time as the annual rings of the tree stumps.

Thus there is a writing upon the wall of cliffs at Cromer, and whoso runs may read it. It tells us, with an authority which cannot be impeached, that the ancient sea-bed of the chalk sea was raised up, and remained dry land, until it was covered with forest, stocked with the great game the spoils of which have rejoiced your geologists. How long it remained in that condition cannot be said; but "the whirligig of time brought its revenges" in those days as in these. That dry land, with the bones and

teeth of generations of long-lived elephants, hidden away among the gnarled roots and dry leaves of its ancient trees, sank gradually to the bottom of the icy sea, which covered it with huge masses of drift and boulder clay. Sea-beasts, such as the walrus, now restricted to the extreme north, paddled about where birds had twittered among the topmost twigs of the fir-trees. How long this state of things endured we know not, but at length it came to an end. The upheaved glacial mud hardened into the soil of modern Norfolk. Forests grew once more, the wolf and the beaver replaced the reindeer and the elephant; and at length what we call the history of England dawned.

Thus you have, within the limits of your own county, proof that the chalk can justly claim a very much greater antiquity than even the oldest physical traces of mankind. But we may go further and demonstrate, by evidence of the same authority as that which testifies to the existence of the father of men, that the chalk is vastly older than Adam himself.

The Book of Genesis informs us that Adam, immediately upon his creation, and before the appearance of Eve, was placed in the Garden of Eden. The problem of the geographical position of Eden has greatly vexed the spirits of the learned in such matters, but there is one point respecting which, so far as I know, no commentator has ever raised a doubt. This is, that of the four rivers which are said to run out of it, Euphrates and Hiddekel are identical with the rivers now known by the names of Euphrates and Tigris.

But the whole country in which these mighty rivers take their origin, and through which they run, is composed of rocks which are either of the same age as the chalk, or of later date. So that the chalk must not only have been formed, but, after its formation, the time required for the deposit of these later rocks, and for their upheaval into dry land, must have elapsed, before the smallest brook which feeds the swift stream of "the great river, the river of Babylon," began to flow.

Thus evidence which cannot be rebutted, and which need not be strengthened, though if time permitted I might indefinitely increase its quantity, compels you to believe that the earth, from the time of the chalk to the present day, has been the theatre of a series of changes as vast in their amount, as they were slow in their progress. The area on which we stand has been first sea

and then land, for at least four alternations; and has remained in each of these conditions for a period of great length.

Nor have these wonderful metamorphoses of sea into land, and of land into sea, been confined to one corner of England. During the chalk period, or "cretaceous epoch," not one of the present great physical features of the globe was in existence. Our great mountain ranges, Pyrenees, Alps, Himalayas, Andes, have all been upheaved since the chalk was deposited, and the cretaceous sea flowed over the sites of Sinai and Ararat.

All this is certain, because rocks of cretaceous or still later date have shared in the elevatory movements which gave rise to these mountain chains, and may be found perched up, in some cases, many thousand feet high upon their flanks. And evidence of equal cogency demonstrates that, though, in Norfolk, the forest-bed rests directly upon the chalk, yet it does so, not because the period at which the forest grew immediately followed that at which the chalk was formed, but because an immense lapse of time, represented elsewhere by thousands of feet of rock, is not indicated at Cromer.

I must ask you to believe that there is no less conclusive proof that a still more prolonged succession of similar changes occurred, before the chalk was deposited. Nor have we any reason to think that the first term in the series of these changes is known. The oldest sea-beds preserved to us are sands, and mud, and pebbles, the wear and tear of rocks which were formed in still older oceans.

But, great as is the magnitude of these physical changes of the world, they have been accompanied by a no less striking series of modifications in its living inhabitants.

All the great classes of animals, beasts of the field, fowls of the air, creeping things, and things which dwell in the waters, flourished upon the globe long ages before the chalk was deposited. Very few, however, if any, of these ancient forms of animal life were identical with those which now live. Certainly, not one of the higher animals was of the same species as any of those now in existence. The beasts of the field, in the days before the chalk, were not our beasts of the field, nor the fowls of the air such as those which the eye of man has seen flying, unless his antiquity dates infinitely further back than we at present surmise. If we could be carried back into those times, we should be as one suddenly set down in Australia before it was colonised. We should see mammals, birds, reptiles, fishes, insects, snails, and the

like, clearly recognisable as such, and yet not one of them would be just the same as those with which we are familiar, and many would be extremely different.

From that time to the present, the population of the world has undergone slow and gradual, but incessant, changes. There has been no grand catastrophe—no destroyer has swept away the forms of life of one period, and replaced them by a totally new creation: but one species has vanished and another has taken its place; creatures of one type of structure have diminished, those of another have increased, as time has passed on. And thus, while the differences between the living creatures of the time before the chalk and those of the present day appear startling, if placed side by side, we are led from one to the other by the most gradual progress, if we follow the course of Nature through the whole series of those relics of her operations which she has left behind.

And it is by the population of the chalk sea that the ancient and the modern inhabitants of the world are most completely connected. The groups which are dying out flourish, side by side, with the groups which are now the dominant forms of life.

Thus the chalk contains remains of those strange flying and swimming reptiles, the pterodactyl, the ichthyosaurus, and the plesiosaurus, which are found in no later deposits, but abounded in preceding ages. The chambered shells called ammonites and belemnites, which are so characteristic of the period preceding the cretaceous, in like manner die with it.

But amongst these fading remainders of a previous state of things, are some very modern forms of life, looking like Yankee pedlars among a tribe of Red Indians. Crocodiles of modern type appear; bony fishes, many of them very similar to existing species, almost supplant the forms of fish which predominate in more ancient seas; and many kinds of living shell-fish first become known to us in the chalk. The vegetation acquires a modern aspect. A few living animals are not even distinguishable as species, from those which existed at that remote epoch. The *Globigerina* of the present day, for example, is not different specifically from that of the chalk; and the same may be said of many other *Foraminiferæ*. I think it probable that critical and unprejudiced examination will show that more than one species of much higher animals have had a similar longevity; but the only example which I can at present give confidently is the snake's-head lamp-shell (*Terebratulina caput serpentis*), which

lives in our English seas and abounded (as *Terebratulina striata* of authors) in the chalk.

The longest line of human ancestry must hide its diminished head before the pedigree of this insignificant shell-fish. We Englishmen are proud to have an ancestor who was present at the Battle of Hastings. The ancestors of *Terebratulina caput serpentis* may have been present at a battle of *Ichthyosauriæ* in that part of the sea which, when the chalk was forming, flowed over the site of Hastings. While all around has changed, this *Terebratulina* has peacefully propagated its species from generation to generation, and stands to this day, as a living testimony to the continuity of the present with the past history of the globe.

Up to this moment I have stated, so far as I know, nothing but well-authenticated facts, and the immediate conclusions which they force upon the mind.

But the mind is so constituted that it does not willingly rest in facts and immediate causes, but seeks always after a knowledge of the remoter links in the chain of causation.

Taking the many changes of any given spot of the earth's surface, from sea to land and from land to sea, as an established fact, we cannot refrain from asking ourselves how these changes have occurred. And when we have explained them—as they must be explained—by the alternate slow movements of elevation and depression which have affected the crust of the earth, we go still further back, and ask, Why these movements?

I am not certain that any one can give you a satisfactory answer to that question. Assuredly I cannot. All that can be said, for certain, is, that such movements are part of the ordinary course of nature, inasmuch as they are going on at the present time. Direct proof may be given, that some parts of the land of the northern hemisphere are at this moment insensibly rising and others insensibly sinking; and there is indirect, but perfectly satisfactory proof, that an enormous area now covered by the Pacific has been deepened thousands of feet since the present inhabitants of that sea came into existence.

Thus there is not a shadow of a reason for believing that the physical changes of the globe, in past times, have been effected by other than natural causes.

Is there any more reason for believing that the concomitant modifications in the form of the living inhabitants of the globe have been brought about in other ways?

Before attempting to answer this question, let us try to form a distinct mental picture of what has happened in some special case.

The crocodiles are animals which, as a group, have a very vast antiquity. They abounded ages before the chalk was deposited; they throng the rivers in warm climates, at the present day. There is a difference in the form of the joints of the back-bone, and in some minor particulars, between the crocodiles of the present epoch and those which lived before the chalk; but, in the cretaceous epoch, as I have already mentioned, the crocodiles had assumed the modern type of structure. Notwithstanding this, the crocodiles of the chalk are not identically the same as those which lived in the times called "older tertiary," which succeeded the cretaceous epoch; and the crocodiles of the older tertiaries are not identical with those of the newer tertiaries, nor are these identical with existing forms. (I leave open the question whether particular species may have lived on from epoch to epoch.) But each epoch has had its peculiar crocodiles; though all, since the chalk, have belonged to the modern type, and differ simply in their proportions, and in such structural particulars as are discernible only to trained eyes.

How is the existence of this long succession of different species of crocodiles to be accounted for?

Only two suppositions seem to be open to us—Either each species of crocodile has been specially created, or it has arisen out of some pre-existing form by the operation of natural causes.

Choose your hypothesis; I have chosen mine. I can find no warranty for believing in the distinct creation of a score of successive species of crocodiles in the course of countless ages of time. Science gives no countenance to such a wild fancy; nor can even the perverse ingenuity of a commentator pretend to discover this sense, in the simple words in which the writer of Genesis records the proceedings of the fifth and sixth days of the Creation.

On the other hand, I see no good reason for doubting the necessary alternative, that all these varied species have been evolved from pre-existing crocodilian forms, by the operation of causes as completely a part of the common order of nature as those which have effected the changes of the inorganic world.

Few will venture to affirm that the reasoning which applies to crocodiles loses its force among other animals, or among plants. If one series of species has come into existence by the operation of

natural causes, it seems folly to deny that all may have arisen in the same way.

A small beginning has led us to a great ending. If I were to put the bit of chalk with which we started into the hot but obscure flame of burning hydrogen, it would presently shine like the sun. It seems to me that this physical metamorphosis is no false image of what has been the result of our subjecting it to a jet of fervent, though nowise brilliant thought to-night. It has become luminous, and its clear rays, penetrating the abyss of the remote past, have brought within our ken some stages of the evolution of the earth. And in the shifting "without haste, but without rest" of the land and sea, as in the endless variation of the forms assumed by living beings, we have observed nothing but the natural product of the forces originally possessed by the substance of the universe.

GEOLOGICAL CONTEMPORANEITY AND PERSISTENT TYPES OF LIFE

MERCHANTS occasionally go through a wholesome, though troublesome and not always satisfactory, process which they term "taking stock." After all the excitement of speculation, the pleasure of gain, and the pain of loss, the trader makes up his mind to face facts and to learn the exact quantity and quality of his solid and reliable possessions.

The man of science does well sometimes to imitate this procedure; and, forgetting for the time the importance of his own small winnings, to re-examine the common stock in trade, so that he may make sure how far the store of bullion in the cellar—on the faith of whose existence so much paper has been circulating—is really the solid gold of truth.

The Anniversary Meeting of the Geological Society seems to be an occasion well suited for an undertaking of this kind—for an inquiry, in fact, into the nature and value of the present results of palæontological investigation; and the more so, as all those who have paid close attention to the late multitudinous discussions in which palæontology is implicated, must have felt the urgent necessity of some such scrutiny.

First in order, as the most definite and unquestionable of all the results of palæontology, must be mentioned the immense extension and impulse given to botany, zoology, and comparative anatomy by the investigation of fossil remains. Indeed, the mass of biological facts has been so greatly increased, and the range of biological speculation has been so vastly widened, by the researches of the geologist and palæontologist, that it is to be feared there are naturalists in existence who look upon geology as Brindley regarded rivers. "Rivers," said the great engineer, "were made to feed canals;" and geology, some seem to think, was solely created to advance comparative anatomy.

Were such a thought justifiable, it could hardly expect to be received with favour by this assembly. But it is not justifiable. Your favourite science has her own great aims independent of all

others; and if, notwithstanding her steady devotion to her own progress, she can scatter such rich alms among her sisters, it should be remembered that her charity is of the sort that does not impoverish, but "blesseth him that gives and him that takes."

Regard the matter as we will, however, the facts remain. Nearly 40,000 species of animals and plants have been added to the Systema Naturæ by palæontological research. This is a living population equivalent to that of a new continent in mere number; equivalent to that of a new hemisphere, if we take into account the small population of insects as yet found fossil, and the large proportion and peculiar organisation of many of the Vertebrata.

But, beyond this, it is perhaps not too much to say that, except for the necessity of interpreting palæontological facts, the laws of distribution would have received less careful study; while few comparative anatomists (and those not of the first order) would have been induced by mere love of detail, as such, to study the minutiæ of osteology, were it not that in such minutiæ lie the only keys to the most interesting riddles offered by the extinct animal world.

These assuredly are great and solid gains. Surely it is matter for no small congratulation that in half a century (for palæontology, though it dawned earlier, came into full day only with Cuvier) a subordinate branch of biology should have doubled the value and the interest of the whole group of sciences to which it belongs.

But this is not all. Allied with geology, palæontology has established two laws of inestimable importance: the first, that one and the same area of the earth's surface has been successively occupied by very different kinds of living beings; the second, that the order of succession established in one locality holds good, approximately, in all.

The first of these laws is universal and irreversible; the second is an induction from a vast number of observations, though it may possibly, and even probably, have to admit of exceptions. As a consequence of the second law, it follows that a peculiar relation frequently subsists between series of strata containing organic remains, in different localities. The series resemble one another not only in virtue of a general resemblance of the organic remains in the two, but also in virtue of a resemblance in the order and character of the serial succession in each. There is a

resemblance of arrangement; so that the separate terms of each series, as well as the whole series, exhibit a correspondence.

Succession implies time; the lower members of an undisturbed series of sedimentary rocks are certainly older than the upper; and when the notion of age was once introduced as the equivalent of succession, it was no wonder that correspondence in succession came to be looked upon as a correspondence in age, or "contemporaneity." And, indeed, so long as relative age only is spoken of, correspondence in succession *is* correspondence in age; it is *relative* contemporaneity.

But it would have been very much better for geology if so loose and ambiguous a word as "contemporaneous" had been excluded from her terminology, and if, in its stead, some term expressing similarity of serial relation, and excluding the notion of time altogether, had been employed to denote correspondence in position in two or more series of strata.

In anatomy, where such correspondence of position has constantly to be spoken of, it is denoted by the word "homology" and its derivatives; and for Geology (which after all is only the anatomy and physiology of the earth) it might be well to invent some single word, such as "homotaxis" (similarity of order), in order to express an essentially similar idea. This, however, has not been done, and most probably the inquiry will at once be made—To what end burden science with a new and strange term in place of one old, familiar, and part of our common language?

The reply to this question will become obvious as the inquiry into the results of palæontology is pushed further.

Those whose business it is to acquaint themselves specially with the works of palæontologists, in fact, will be fully aware that very few, if any, would rest satisfied with such a statement of the conclusions of their branch of biology as that which has just been given.

Our standard repertories of palæontology profess to teach us far higher things—to disclose the entire succession of living forms upon the surface of the globe; to tell us of a wholly different distribution of climatic conditions in ancient times; to reveal the character of the first of all living existences; and to trace out the law of progress from them to us.

It may not be unprofitable to bestow on these professions a somewhat more critical examination than they have hitherto

received, in order to ascertain how far they rest on an irrefragable basis, or whether, after all, it might not be well for palæontologists to learn a little more carefully that scientific "ars artium," the art of saying "I don't know." And to this end let us define somewhat more exactly the extent of these pretensions of palæontology.

Every one is aware that Professor Bronn's "Untersuchungen" and Professor Pictet's "Traité de Paléontologie" are works of standard authority, familiarly consulted by every working palæontologist. It is desirable to speak of these excellent books, and of their distinguished authors, with the utmost respect, and in a tone as far as possible removed from carping criticism; indeed, if they are specially cited in this place, it is merely in justification of the assertion that the following propositions, which may be found implicitly, or explicitly, in the works in question, are regarded by the mass of palæontologists and geologists, not only on the Continent but in this country, as expressing some of the best-established results of palæontology. Thus:—

Animals and plants began their existence together, not long after the commencement of the deposition of the sedimentary rocks, and then succeeded one another, in such a manner, that totally distinct faunæ and floræ occupied the whole surface of the earth, one after the other, and during distinct epochs of time.

A geological formation is the sum of all the strata deposited over the whole surface of the earth during one of these epochs: a geological fauna or flora is the sum of all the species of animals or plants which occupied the whole surface of the globe, during one of these epochs.

The population of the earth's surface was at first very similar in all parts, and only from the middle of the Tertiary epoch onwards began to show a distinct distribution in zones.

The constitution of the original population, as well as the numerical proportions of its members, indicates a warmer and, on the whole, somewhat tropical climate, which remained tolerably equable throughout the year. The subsequent distribution of living beings in zones is the result of a gradual lowering of the general temperature, which first began to be felt at the poles.

It is not now proposed to inquire whether these doctrines are

true or false; but to direct your attention to a much simpler though very essential preliminary question—What is their logical basis? what are the fundamental assumptions upon which they all logically depend? and what is the evidence on which those fundamental propositions demand our assent?

These assumptions are two: the first, that the commencement of the geological record is coeval with the commencement of life on the globe; the second, that geological contemporaneity is the same thing as chronological synchrony. Without the first of these assumptions there would of course be no ground for any statement respecting the commencement of life; without the second, all the other statements cited, every one of which implies a knowledge of the state of different parts of the earth at one and the same time, will be no less devoid of demonstration.

The first assumption obviously rests entirely on negative evidence. This is, of course, the only evidence that ever can be available to prove the commencement of any series of phenomena; but, at the same time, it must be recollected that the value of negative evidence depends entirely on the amount of positive corroboration it receives. If A.B. wishes to prove an *alibi*, it is of no use for him to get a thousand witnesses simply to swear that they did not see him in such and such a place, unless the witnesses are prepared to prove that they must have seen him had he been there. But the evidence that animal life commenced with the Lingula-flags, *e.g.*, would seem to be exactly of this unsatisfactory uncorroborated sort. The Cambrian witnesses simply swear they "haven't seen anybody their way"; upon which the counsel for the other side immediately puts in ten or twelve thousand feet of Devonian sandstones to make oath they never saw a fish or a mollusk, though all the world knows there were plenty in their time.

But then it is urged that, though the Devonian rocks in one part of the world exhibit no fossils, in another they do, while the lower Cambrian rocks nowhere exhibit fossils, and hence no living being could have existed in their epoch.

To this there are two replies: the first, that the observational basis of the assertion that the lowest rocks are nowhere fossiliferous is an amazingly small one, seeing how very small an area, in comparison to that of the whole world, has yet been fully searched; the second, that the argument is good for nothing unless the unfossiliferous rocks in question were not only *contemporaneous* in the geological sense, but *synchronous* in the

chronological sense. To use the *alibi* illustration again. If a man wishes to prove he was in neither of two places, A and B, on a given day, his witnesses for each place must be prepared to answer for the whole day. If they can only prove that he was not at A in the morning, and not at B in the afternoon, the evidence of his absence from both is *nil*, because he might have been at B in the morning and at A in the afternoon.

Thus everything depends upon the validity of the second assumption. And we must proceed to inquire what is the real meaning of the word "contemporaneous" as employed by geologists. To this end a concrete example may be taken.

The Lias of England and the Lias of Germany, the Cretaceous rocks of Britain and the Cretaceous rocks of Southern India, are termed by geologists "contemporaneous" formations; but whenever any thoughtful geologist is asked whether he means to say that they were deposited synchronously, he says, "No,—only within the same great epoch." And if, in pursuing the inquiry, he is asked what may be the approximate value in time of a "great epoch"—whether it means a hundred years, or a thousand, or a million, or ten million years—his reply is, "I cannot tell."

If the further question be put, whether physical geology is in possession of any met od by which the actual synchrony (or the reverse) of any two distant deposits can be ascertained, no such method can be heard of; it being admitted by all the best authorities that neither similarity of mineral composition, nor of physical character, nor even direct continuity of stratum, are *absolute* proofs of the synchronism of even approximated sedimentary strata: while, for distant deposits, there seems to be no kind of physical evidence attainable of a nature competent to decide whether such deposits were formed simultaneously, or whether they possess any given difference of antiquity. To return to an example already given. All competent authorities will probably assent to the proposition that physical geology does not enable us in any way to reply to this question—Were the British Cretaceous rocks deposited at the same time as those of India, or are they a million of years younger or a million of years older?

Is palæontology able to succeed where physical geology fails? Standard writers on palæontology, as has been seen, assume that she can. They take it for granted, that deposits containing similar organic remains are synchronous—at any rate in a broad

sense; and yet, those who will study the eleventh and twelfth chapters of Sir Henry De La Beche's remarkable "Researches in Theoretical Geology," published now nearly thirty years ago, and will carry out the arguments there most luminously stated to their logical consequences, may very easily convince themselves that even absolute identity of organic contents is no proof of the synchrony of deposits, while absolute diversity is no proof of difference of date. Sir Henry De La Beche goes even further, and adduces conclusive evidence to show that the different parts of one and the same stratum, having a similar composition throughout, containing the same organic remains, and having similar beds above and below it, may yet differ to any conceivable extent in age.

Edward Forbes was in the habit of asserting that the similarity of the organic contents of distant formations was *primâ facie* evidence, not of their similarity, but of their difference of age; and holding as he did the doctrine of single specific centres, the conclusion was as legitimate as any other; for the two districts must have been occupied by migration from one of the two, or from an intermediate spot, and the chances against exact coincidence of migration and of imbedding are infinite.

In point of fact, however, whether the hypothesis of single or of multiple specific centres be adopted, similarity of organic contents cannot possibly afford any proof of the synchrony of the deposits which contain them; on the contrary, it is demonstrably compatible with the lapse of the most prodigious intervals of time, and with the interposition of vast changes in the organic and inorganic worlds, between the epochs in which such deposits were formed.

On what amount of similarity of their faunæ is the doctrine of the contemporaneity of the European and of the North American Silurians based? In the last edition of Sir Charles Lyell's "Elementary Geology" it is stated, on the authority of a former President of this Society, the late Daniel Sharpe, that between 30 and 40 per cent. of the species of Silurian Mollusca are common to both sides of the Atlantic. By way of due allowance for further discovery, let us double the lesser number and suppose that 60 per cent. of the species are common to the North American and the British Silurians. Sixty per cent. of species in common is, then, proof of contemporaneity.

Now suppose that, a million or two of years hence, when Britain has made another dip beneath the sea and has come up again,

some geologist applies this doctrine, in comparing the strata laid bare by the upheaval of the bottom, say, of St. George's Channel with what may then remain of the Suffolk Crag. Reasoning in the same way, he will at once decide the Suffolk Crag and the St. George's Channel beds to be contemporaneous; although we happen to know that a vast period (even in the geological sense) of time, and physical changes of almost unprecedented extent, separate the two.

But if it be a demonstrable fact that strata containing more than 60 or 70 per cent. of species of Mollusca in common, and comparatively close together, may yet be separated by an amount of geological time sufficient to allow of some of the greatest physical changes the world has seen, what becomes of that sort of contemporaneity the sole evidence of which is a similarity of facies, or the identity of half a dozen species, or of a good many genera?

And yet there is no better evidence for the contemporaneity assumed by all who adopt the hypotheses of universal faunæ and floræ, of a universally uniform climate, and of a sensible cooling of the globe during geological time.

There seems, then, no escape from the admission that neither physical geology nor palæontology possesses any method by which the absolute synchronism of two strata can be demonstrated. All that geology can prove is local order of succession. It is mathematically certain that, in any given vertical linear section of an undisturbed series of sedimentary deposits, the bed which lies lowest is the oldest. In many other vertical linear sections of the same series, of course, corresponding beds will occur in a similar order; but, however great may be the probability, no man can say with absolute certainty that the beds in the two sections were synchronously deposited. For areas of moderate extent, it is doubtless true that no practical evil is likely to result from assuming the corresponding beds to be synchronous or strictly contemporaneous; and there are multitudes of accessory circumstances which may fully justify the assumption of such synchrony. But the moment the geologist has to deal with large areas or with completely separated deposits, the mischief of confounding that "homotaxis" or "similarity of arrangement," which *can* be demonstrated, with "synchrony" or "identity of date," for which there is not a shadow of proof, under the one common term of "contem-

poraneity" becomes incalculable, and proves the constant source of gratuitous speculations.

For anything that geology or palæontology are able to show to the contrary, a Devonian fauna and flora in the British Islands may have been contemporaneous with Silurian life in North America, and with a Carboniferous fauna and flora in Africa. Geographical provinces and zones may have been as distinctly marked in the Palæozoic epoch as at present, and those seemingly sudden appearances of new genera and species, which we ascribe to new creation, may be simple results of migration.

It may be so; it may be otherwise. In the present condition of our knowledge and of our methods, one verdict—"not proven, and not proveable"—must be recorded against all the grand hypotheses of the palæontologist respecting the general succession of life on the globe. The order and nature of terrestrial life as a whole are open questions. Geology at present provides us with most valuable topographical records, but she has not the means of working them into a universal history. Is such a universal history, then, to be regarded as unattainable? Are all the grandest and most interesting problems which offer themselves to the geological student, essentially insoluble? Is he in the position of a scientific Tantalus—doomed always to thirst for a knowledge which he cannot obtain? The reverse is to be hoped; nay, it may not be impossible to indicate the source whence help will come.

In commencing these remarks, mention was made of the great obligations under which the naturalist lies to the geologist and palæontologist. Assuredly the time will come when these obligations will be repaid tenfold, and when the maze of the world's past history, through which the pure geologist and the pure palæontologist find no guidance, will be securely threaded by the clue furnished by the naturalist.

All who are competent to express an opinion on the subject are at present agreed that the manifold varieties of animal and vegetable form have not either come into existence by chance, nor result from capricious exertions of creative power; but that they have taken place in a definite order, the statement of which order is what men of science term a natural law. Whether such a law is to be regarded as an expression of the mode of operation of natural forces, or whether it is simply a statement of the manner in which a supernatural power has thought fit to act, is a

secondary question, so long as the existence of the law and the possibility of its discovery by the human intellect are granted. But he must be a half-hearted philosopher who, believing in that possibility, and having watched the gigantic strides of the biological sciences during the last twenty years, doubts that science will sooner or later make this further step, so as to become possessed of the law of evolution of organic forms—of the unvarying order of that great chain of causes and effects of which all organic forms, ancient and modern, are the links. And then, if ever, we shall be able to begin to discuss, with profit, the questions respecting the commencement of life, and the nature of the successive populations of the globe, which so many seem to think are already answered.

The preceding arguments make no particular claim to novelty; indeed they have been floating more or less distinctly before the minds of geologists for the last thirty years; and if, at the present time, it has seemed desirable to give them more definite and systematic expression, it is because palæontology is every day assuming a greater importance, and now requires to rest on a basis the firmness of which is thoroughly well assured. Among its fundamental conceptions, there must be no confusion between what is certain and what is more or less probable.[1] But, pending the construction of a surer foundation than palæontology now possesses, it may be instructive, assuming for the nonce the general correctness of the ordinary hypothesis of geological contemporaneity, to consider whether the deductions which are ordinarily drawn from the whole body of palæontological facts are justifiable.

The evidence on which such conclusions a e based is of two kinds, negative and positive. The value of negative evidence, in connection with this inquiry, has been so fully and clearly discussed in an address from the chair of this Society,[2] which none of us have forgotten, that nothing need at present be said about it; the more, as the considerations which have been laid before you have certainly not tended to increase your estimation of such evidence. It will be preferable to turn to the positive facts of palæontology, and to inquire what they tell us.

We are all accustomed to speak of the number and the extent

[1] "Le plus grand service qu'on puisse rendre à la science est d'y faire place nette avant d'y rien construire."—*Cuvier*.

[2] Anniversary Address for 1851, "Quart. Journ. Geol. Soc." vol. vii.

of the changes in the living population of the globe during geological time as something enormous: and indeed they are so, if we regard only the negative differences which separate the older rocks from the more modern, and if we look upon specific and generic changes as great changes, which from one point of view they truly are. But leaving the negative differences out of consideration, and looking only at the positive data furnished by the fossil world from a broader point of view—from that of the comparative anatomist who has made the study of the greater modifications of animal form his chief buisness—a surprise of another kind dawns upon the mind; and under *this* aspect the smallness of the total change becomes as astonishing as was its greatness under the other.

There are two hundred known orders of plants; of these not one is certainly known to exist exclusively in the fossil state. The whole lapse of geological time has as yet yielded not a single new ordinal type of vegetable structure.[1]

The positive change in passing from the recent to the ancient animal world is greater, but still singularly small. No fossil animal is so distinct from those now living as to require to be arranged even in a separate class from those which contain existing forms. It is only when we come to the orders, which may be roughly estimated at about a hundred and thirty, that we meet with fossil animals so distinct from those now living as to require orders for themselves; and these do not amount, on the most liberal estimate, to more than about 10 per cent. of the whole.

There is no certainly known extinct order of Protozoa; there is but one among the Cœlenterata—that of the rugose corals; there is none among the Mollusca; there are three, the Cystidea, Blastoidea, and Edrioasterida, among the Echinoderms; and two, the Trilobita and Eurypterida, among the Crustacea; making altogether five for the great subkingdom of Annulosa. Among Vertebrates there is no ordinally distinct fossil fish; there is only one extinct order of Amphibia—the Labyrinthodonts; but there are at least four distinct orders of Reptilia, viz. the Ichthyosauria, Plesiosauria, Pterosauria, Dinosauria, and perhaps another or two. There is no known extinct order of Birds, and no certainly known extinct order of Mammals, the ordinal distinctness of the "Toxodontia" being doubtful.

The objection that broad statements of this kind, after all,

[1] See Hooker's "Introductory Essay to the Flora of Tasmania," p. xxiii.

rest largely on negative evidence is obvious, but it has less force than may at first be supposed; for, as might be expected from the circumstances of the case, we possess more abundant positive evidence regarding Fishes and marine Mollusks than respecting any other forms of animal life; and yet these offer us, through the whole range of geological time, no species ordinally distinct from those now living; while the far less numerous class of Echinoderms presents three, and the Crustacea two such orders, though none of these come down later than the Palæozoic age. Lastly, the Reptilia present the extraordinary and exceptional phenomenon of as many extinct as existing orders, if not more; the four mentioned maintaining their existence from the Lias to the Chalk inclusive.

Some years ago one of your Secretaries pointed out another kind of positive palæontological evidence tending towards the same conclusion—afforded by the existence of what he termed "persistent types" of vegetable and of animal life.[1] He stated, on the authority of Dr. Hooker, that there are Carboniferous plants which appear to be generically identical with some now living; that the cone of the Oolitic *Araucaria* is hardly distinguishable from that of an existing species; that a true *Pinus* appears in the Purbecks and a *Juglans* in the Chalk; while, from the Bagshot Sands, a *Banksia*, the wood of which is not distinguishable from that of species now living in Australia, had been obtained.

Turning to the animal kingdom, he affirmed the tabulate corals of the Silurian rocks to be wonderfully like those which now exist; while even the families of the Aporosa were all represented in the older Mesozoic rocks.

Among the Mollusca similar facts were adduced. Let it be borne in mind that *Avicula*, *Mytilus*, *Chiton*, *Natica*, *Patella*, *Trochus*, *Discina*, *Orbicula*, *Lingula*, *Rhynchonella*, and *Nautilus*, all of which are existing *genera*, are given without a doubt as Silurian in the last edition of "Siluria"; while the highest forms of the highest Cephalopods are represented in the Lias by a genus *Belemnoteuthis*, which presents the closest relation to the existing *Loligo*.

The two highest groups of the Annulosa, the Insecta and the Arachnida, are represented in the Coal either by existing genera

[1] See the abstract of a Lecture "On the Persistent Types of Animal Life," in the "Notices of the Meetings of the Royal Institution of Great Britain."—June 3, 1859, vol. iii. p. 151.

or by forms differing from existing genera in quite minor peculiarities.

Turning to the Vertebrata, the only palæozoic Elasmobranch Fish of which we have any complete knowledge is the Devonian and Carboniferous *Pleuracanthus*, which differs no more from existing Sharks than these do from one another.

Again, vast as is the number of undoubtedly Ganoid fossil Fishes, and great as is their range in time, a large mass of evidence has recently been adduced to show that almost all those respecting which we possess sufficient information, are referable to the same sub-ordinal groups as the existing *Lepidosteus*, *Polypterus*, and Sturgeon; and that a singular relation obtains between the older and the younger Fishes; the former, the Devonian Ganoids, being almost all members of the same sub-order as *Polypterus*, while the Mesozoic Ganoids are almost all similarly allied to *Lepidosteus*.[1]

Again, what can be more remarkable than the singular constancy of structure preserved throughout a vast period of time by the family of the Pycnodonts and by that of the true Cœlacanths: the former persisting, with but insignificant modifications, from the Carboniferous to the Tertiary rocks, inclusive; the latter existing, with still less change, from the Carboniferous rocks to the Chalk, inclusive?

Among Reptiles, the highest living group, that of the Crocodilia, is represented at the early part of the Mesozoic epoch, by species identical in the essential characters of their organisation with those now living, and differing from the latter only in such matters as the form of the articular facets of the vertebral centra, in the extent to which the nasal passages are separated from the cavity of the mouth by bone, and in the proportions of the limbs.

And even as regards the Mammalia, the scanty remains of Triassic and Oolitic species afford no foundation for the supposition that the organisation of the oldest forms differed nearly so much from some of those which now live as these differ from one another.

It is needless to multiply these instances; enough has been said to justify the statement that, in view of the immense diversity of known animal and vegetable forms, and the

[1] "Memoirs of the Geological Survey of the United Kingdom.—Decade x. Preliminary Essay upon the Systematic Arrrangement of the Fishes of the Devonian Epoch."

enormous lapse of time indicated by the accumulation of fossiliferous strata, the only circumstance to be wondered at is, not that the changes of life, as exhibited by positive evidence, have been so great, but that they have been so small.

Be they great or small, however, it is desirable to attempt to estimate them. Let us therefore take each great division of the animal world in succession, and whenever an order or a family can be shown to have had a prolonged existence, let us endeavour to ascertain how far the later members of the group differ from the earlier ones. If these later members, in all or in many cases, exhibit a certain amount of modification, the fact is, so far, evidence in favour of a general law of change; and, in a rough way, the rapidity of that change will be measured by the demonstrable amount of modification. On the other hand, it must be recollected that the absence of any modification, while it may leave the doctrine of the existence of a law of change without positive support, cannot possibly disprove all forms of that doctrine, though it may afford a sufficient refutation of many of them.

The *Protozoa.*—The Protozoa are represented throughout the whole range of geological series, from the Lower Silurian formation to the present day. The most ancient forms recently made known by Ehrenberg are exceedingly like those which now exist: no one has ever pretended that the difference between any ancient and any modern Foraminifera is of more than generic value; nor are the oldest Foraminifera either simpler, more embryonic, or less differentiated, than the existing forms.

The *Cœlenterata.*—The Tabulate Corals have existed from the Silurian epoch to the present day, but I am not aware that the ancient *Heliolites* possesses a single mark of a more embryonic or less differentiated character, or less high organisation, than the existing *Heliopora.* As for the Aporose Corals, in what respect is the Silurian *Palæocyclus* less highly organised or more embryonic than the modern *Fungia*, or the Liassic Aporosa than the existing members of the same families?

The *Mollusca.*—In what sense is the living *Waldheimia* less embryonic, or more specialised, than the palæozoic *Spirifer*; or the existing *Rhynchonellæ, Cranicæ, Discinæ, Lingulæ*, than the Silurian species of the same genera? In what sense can *Loligo* or *Spirula* be said to be more specialised, or less embryonic, than *Belemnites*; or the modern species of Lamellibranch and

Gasteropod genera, than the Silurian species of the same genera?

The *Annulosa*.—The Carboniferous Insecta and Arachnida are neither less specialised, not more embryonic, than these that now live, nor are the Liassic Cirripedia and Macrura; while several of the Brachyura, which appear in the Chalk, belong to existing genera; and none exhibit either an intermediate, or an embryonic, character.

The *Vertebrata*.—Among fishes I have referred to the Cœlacanthini (comprising the genera *Cœlacanthus*, *Holophagus*, *Undina*, and *Macropoma*) as affording an example of a persistent type; and it is most remarkable to note the smallness of the differences between any of these fishes (affecting at most the proportions of the body and fins, and the character and sculpture of the scales), notwithstanding their enormous range in time. In all the essentials of its very peculiar structure, the *Macropoma* of the Chalk is identical with the *Cœlacanthus* of the Coal. Look at the genus *Lepidotus*, again, persisting without a modification of importance from the Lias to the Eocene formation, inclusive.

Or among the Teleostei—in what respect is the *Beryx* of the Chalk more embryonic or less differentiated, than *Beryx lineatus* of King George's Sound?

Or to turn to the higher Vertebrata—in what sense are the Liassic Chelonia inferior to those which now exist? How are the Cretaceous Ichthyosauria, Plesiosauria, or Pterosauria less embryonic, or more differentiated, species than those of the Lias?

Or lastly, in what circumstance is the *Phascolotherium* more embryonic, or of a more generali ed type, than the modern Opossum; or a *Lophiodon*, or a *Palæotherium*, than a modern *Tapirus* or *Hyrax*?

These examples might be almost indefinitely multiplied, but surely they are sufficient to prove that the only safe and unquestionable testimony we can procure—positive evidence—fails to demonstrate any sort of progressive modification towards a less embryonic or less generalised type in a great many groups of animals of long-continued geological existence. In these groups there is abundant evidence of variation—none of what is ordinarily understood as progression; and, if the known geological record is to be regarded as even any considerable fragment of the whole, it is inconceivable that any theory of a necessarily

progressive development can stand, for the numerous orders and families cited afford no trace of such a process.

But it is a most remarkable fact, that, while the groups which have been mentioned, and many besides, exhibit no sign of progressive modification, there are others, coexisting with them, under the same conditions, in which more or less distinct indications of such a process seem to be traceable. Among such indications I may remind you of the predominance of Holostome Gasteropoda in the older rocks as compared with that of Siphonostone Gasteropoda in the later. A case less open to the objection of negative evidence, however, is that afforded by the Tetrabranchiate Cephalopoda, the forms of the shells and of the septal sutures exhibiting a certain increase of complexity in the newer genera. Here, however, one is met at once with the occurrence of *Orthoceras* and *Baculites* at the two ends of the series, and of the fact that one of the simplest genera, *Nautilus*, is that which now exists.

The Crinoidea, in the abundance of stalked forms in the ancient formations as compared with their present rarity, seem to present us with a fair case of modification from a more embryonic towards a less embryonic condition. But then, on careful consideration of the facts, the objection arises that the stalk, calyx, and arms of the palæozoic Crinoid are exceedingly different from the corresponding organs of a larval *Comatula*; and it might with perfect justice be argued that *Actinocrinus* and *Eucalyptocrinus*, for example, depart to the full as widely, in one direction, from the stalked embryo of *Comatula*, as *Comatula* itself does in the other.

The Echinidea, again, are frequently quoted as exhibiting a gradual passage from a more generalised to a more specialised type, seeing that the elongated, or oval, Spatangoids appear after the spheroidal Echinoids. But here it might be argued, on the other hand, that the spheroidal Echinoids, in reality, depart further from the general plan and from the embryonic form than the elongated Spatangoids do; and that the peculiar dental apparatus and the pedicellariæ of the former are marks of at least as great differentiation as the petaloid ambulacra and semitæ of the latter.

Once more, the prevalence of Macrurous before Brachyurous Podophthalmia is, apparently, a fair piece of evidence in favour of progressive modification in the same order of Crustacea; and yet the case will not stand much sifting, seeing that the

Macrurous Podophthalmia depart as far in one direction from the common type of Podophthalmia, or from any embryonic condition of the Brachyura, as the Brachyura do in the other; and that the middle terms between Macrura and Brachyura—the Anomura—are little better represented in the older Mesozoic rocks than the Brachyura are.

None of the cases of progressive modification which are cited from among the Invertebrata appear to me to have a foundation less open to criticism than these; and if this be so, no careful reasoner would, I think, be inclined to lay very great stress upon them. Among the Vertebrata, however, there are a few examples which appear to be far less open to objection.

It is, in fact, true of several groups of Vertebrata which have lived through a considerable range of time, that the endoskeleton (more particularly the spinal column) of the older genera presents a less ossified, and so far less differentiated, condition than that of the younger genera. Thus the Devonian Ganoids, though almost all members of the same sub-order as *Polypterus*, and presenting numerous important resemblances to the existing genus, which possesses biconcave vertebræ, are, for the most part, wholly devoid of ossified vertebral centra. The Mesozoic Lepidosteidæ, again, have, at most, biconcave vertebræ, while the existing *Lepidosteus* has Salamandroid, opisthocœlous, vertebræ. So, none of the Palæozoic Sharks have shown themselves to be possessed of ossified vertebræ, while the majority of modern Sharks possess such vertebræ. Again, the more ancient Crocodilia and Lacertilia have vertebræ with the articular facets of their centra flattened or biconcave, while the modern members of the same group have them procœlous. But the most remarkable examples of progressive modification of the vertebral column, in correspondence with geological age, are those afforded by the Pycnodonts among fish, and the Labyrinthodonts among Amphibia.

The late able ichthyologist Heckel pointed out the fact, that, while the Pycnodonts never possess true vertebral centra, they differ in the degree of expansion and extension of the ends of the bony arches of the vertebræ upon the sheath of the notochord; the Carboniferous forms exhibiting hardly any such expansion, while the Mesozoic genera present a greater and greater development, until, in the Tertiary forms, the expanded ends become suturally united so as to form a sort of false vertebra. Hermann von Meyer, again, to whose luminous researches we are indebted

for our present large knowledge of the organisation of the older Labyrinthodonts, has proved that the Carboniferous *Archegosaurus* had very imperfectly developed vertebral centra, while the Triassic *Mastodonsaurus* had the same parts completely ossified.[1]

The regularity and evenness of the dentition of the *Anoplotherium*, as contrasted with that of existing Artiodactyles, and the assumed nearer approach of the dentition of certain ancient Carnivores to the typical arrangement, have also been cited as exemplifications of a law of progressive development, but I know of no other cases based on positive evidence which are worthy of particular notice.

What then does an impartial survey of the positively ascertained truths of palæontology testify in relation to the common doctrines of progressive modification, which suppose that modification to have taken place by a necessary progress from more o less embryonic forms, or from more to less generalised types, within the limits of the period represented by the fossiliferous rocks?

It negatives those doctrines; for it either shows us no evidence of any such modification, or demonstrates it to have been very slight; and as to the nature of that modification, it yields no evidence whatsoever that the earlier members of any long-continued group were more generali ed in structure than the later ones. To a certain extent, indeed, it may be said that imperfect ossification of the vertebral column is an embryonic character; but, on the other hand, it would be extremely incorrect to suppose that the vertebral columns of the older Vertebrata are in any sense embryonic in their whole structure.

Obviously, if the earliest fossiliferous rocks now known are coeval with the commencement of life, and if their contents give us any just conception of the nature and the extent of the earliest fauna and flora, the insignificant amount of modification which can be demonstrated to have taken place in any one group of animals, or plants, is quite incompatible with the hypothesis that all living forms are the results of a necessary process of progressive development, entirely comprised within the time represented by the fossiliferous rocks.

Contrariwise, any admissible hypothesis of progressive

[1] As this Address is passing through the press (March 7, 1862), evidence lies before me of the existence of a new Labyrinthodont (*Pholidogaster*) from the Edinburgh coal-field with well-ossified vertebral centra.

modification must be compatible with persistence without progression through indefinite periods. And should such an hypothesis eventually be proved to be true, in the only way in which it can be demonstrated, viz.. by observation and experiment upon the existing forms of life, the conclusion will inevitably present itself, that the Palæozoic, Mesozoic, and Cainozoic faunæ and floræ, taken together, bear somewhat the same proportion to the whole series of living beings which have occupied this globe, as the existing fauna and flora do to them.

Such are the results of palæontology as they appear, and have for some years appeared, to the mind of an inquirer who regards that study simply as one of the applications of the great biological sciences, and who desires to see it placed upon the same sound basis as other branches of physical inquiry. If the arguments which have been brought forward are valid, probably no one, in view of the present state of opinion, will be inclined to think the time wasted which has been spent upon their elaboration.

ON THE ADVISABLENESS OF IMPROVING NATURAL KNOWLEDGE

A LAY SERMON, DELIVERED AT ST. MARTIN'S HALL, ON SUNDAY, JANUARY 7, 1866.

THIS time two hundred years ago—in the beginning of January, 1666—those of our forefathers who inhabited this great and ancient city, took breath between the shocks of two fearful calamities, one not quite past, although its fury had abated; the other to come.

Within a few yards of the very spot on which we are assembled, so the tradition runs, that painful and deadly malady, the plague, appeared in the latter months of 1664; and, though no new visitor, smote the people of England, and especially of her capital, with a violence unknown before, in the course of the following year. The hand of a master has pictured what happened in those dismal months; and in that truest of fictions, "The History of the Plague Year," Defoe shows death, with every accompaniment of pain and terror, stalking through the narrow streets of old London, and changing their busy hum into a silence broken only by the wailing of the mourners of fifty thousand dead; by the woeful denunciations and mad prayers of fanatics; and by the madder yells of despairing profligates.

But, about this time in 1666, the death rate had sunk to nearly its ordinary amount; a case of plague occurred only here and there, and the richer citizens who had flown from the pest had returned to their dwellings. The remnant of the people began to toil at the accustomed round of duty, or of pleasure; and the stream of city life bid fair to flow back along its old bed, with renewed and uninterrupted vigour.

The newly-kindled hope was deceitful. The great plague, indeed, returned no more; but what it had done for the Londoners, the great fire, which broke out in the autumn of 1666, did for London; and, in September of that year, a heap of ashes and the indestructible energy of the people were all that remained of the glory of five-sixths of the city within the walls.

Our forefathers had their own ways of accounting for each of these calamities. They submitted to the plague in humility and in penitence, for they believed it to be the judgment of God. But towards the fire they were furiously indignant, interpreting it as the effect of the malice of man,—as the work of the Republicans, or of the Papists, according as their prepossessions ran in favour of loyalty or of Puritanism.

It would, I fancy, have fared but ill with one who, standing where I now stand, in what was then a thickly-peopled and fashionable part of London, should have broached to our ancestors the doctrine which I now propound to you—that all their hypotheses were alike wrong; that the plague was no more, in their sense, a Divine judgment, than the fire was the work of any political, or of any religious, sect; but that they were themselves the authors of both plague and fire, and that they must look to themselves to prevent the recurrence of calamities, to all appearance so peculiarly beyond the reach of human control—so evidently the result of the wrath of God, or of the craft and subtlety of an enemy.

And one may picture to oneself how harmoniously the holy cursing of the Puritan of that day would have chimed in with the unholy cursing and the crackling wit of the Rochesters and Sedleys, and with the revilings of the political fanatics, if my imaginary plain dealer had gone on to say that, if the return of such misfortunes were ever rendered impossible, it would not be in virtue of the victory of the faith of Laud, or of that of Milton; and, as little, by the triumph of republicanism, as by that of monarchy. But that the one thing needful for compassing this end was, that the people of England should second the efforts of an insignificant corporation, the establishment of which, a few years before the epoch of the great plague and the great fire, had been as little noticed, as they were conspicuous.

Some twenty years before the outbreak of the plague a few calm and thoughtful students banded themselves together for the purpose, as they phrased it, of "improving natural knowledge." The ends they proposed to attain cannot be stated more clearly than in the words of one of the founders of the organisation:—

"Our business was (precluding matters of theology and state affairs) to discourse and consider of philosophical enquiries, and such as related thereunto:—as Physick, Anatomy, Geometry,

Astronomy, Navigation, Staticks, Magneticks, Chymicks, Mechanicks, and Natural Experiments; with the state of these studies and their cultivation at home and abroad. We then discoursed of the circulation of the blood, the valves in the veins, the venæ lacteæ, the lymphatic vessels, the Copernican hypothesis, the nature of comets and new stars, the satellites of Jupiter, the oval shape (as it then appeared) of Saturn, the spots on the sun and its turning on its own axis, the inequalities and selenography of the moon, the several phases of Venus and Mercury, the improvement of telescopes and grinding of glasses for that purpose, the weight of air, the possibility or impossibility of vacuities and nature's abhorrence thereof, the Torricellian experiment in quicksilver, the descent of heavy bodies and the degree of acceleration therein, with divers other things of like nature, some of which were then but new discoveries, and others not so generally known and embraced as now they are; with other things appertaining to what hath been called the New Philosophy, which from the times of Galileo at Florence, and Sir Francis Bacon (Lord Verulam) in England, hath been much cultivated in Italy, France, Germany, and other parts abroad, as well as with us in England."

The learned Dr. Wallis, writing in 1696, narrates in these words, what happened half a century before, or about 1645. The associates met at Oxford, in the rooms of Dr. Wilkins, who was destined to become a bishop; and subsequently coming together in London, they attracted the notice of the king. And it is a strange evidence of the taste for knowledge which the most obviously worthless of the Stuarts shared with his father and grandfather, that Charles the Second was not content with saying witty things about his philosophers, but did wise things with regard to them. For he not only bestowed upon them such attention as he could spare from his poodles and his mistresses, but, being in his usual state of impecuniosity, begged for them of the Duke of Ormond; and, that step being without effect, gave them Chelsea College, a charter, and a mace: crowning his favours in the best way they could be crowned, by burdening them no further with royal patronage or state interference.

Thus it was that the half-dozen young men, studious of the "New Philosophy," who met in one another's lodgings in Oxford or in London, in the middle of the seventeenth century, grew in numerical and in real strength, until, in its latter part, the "Royal Society for the Improvement of Natural Knowledge"

had already become famous, and had acquired a claim upon the veneration of Englishmen, which it has ever since retained, as the principal focus of scientific activity in our islands, and the chief champion of the cause it was formed to support.

It was by the aid of the Royal Society that Newton published his "Principia." If all the books in the world, except the "Philosophical Transactions," were destroyed, it is safe to say that the foundations of physical science would remain unshaken, and that the vast intellectual progress of the last two centuries would be largely, though incompletely, recorded. Nor have any signs of halting or of decrepitude manifested themselves in our own times. As in Dr. Wallis's days, so in these, "our business is, precluding theology and state affairs, to discourse and consider of philosophical enquiries." But our "Mathematick" is one which Newton would have to go to school to learn; our "Staticks, Mechanicks, Magneticks, Chymicks, and Natural Experiments" constitute a mass of physical and chemical knowledge, a glimpse at which would compensate Galileo for the doings of a score of inquisitorial cardinals; our "Physick" and "Anatomy" have embraced such infinite varieties of being, have laid open such new worlds in time and space, have grappled, not unsuccessfully, with such complex problems, that the eyes of Vesalius and of Harvey might be dazzled by the sight of the tree that has grown out of their grain of mustard seed.

The fact is perhaps rather too much, than too little, forced upon one's notice, nowadays, that all this marvellous intellectual growth has a no less wonderful expression in practical life; and that, in this respect, if in no other, the movement symbolised by the progress of the Royal Society stands without a parallel in the history of mankind.

A series of volumes as bulky as the Transactions of the Royal Society might possibly be filled with the subtle speculations of the schoolmen; not improbably, the obtaining a mastery over the products of mediæval thought might necessitate an even greater expenditure of time and of energy than the acquirement of the "New Philosophy;" but though such work engrossed the best intellects of Europe for a longer time than has elapsed since the great fire, its effects were "writ in water," so far as our social state is concerned.

On the other hand, if the noble first President of the Royal Society could revisit the upper air and once more gladden his

eyes with a sight of the familiar mace, he would find himself in the midst of a material civilisation more different from that of his day, than that of the seventeenth, was from that of the first, century. And if Lord Brouncker's native sagacity had not deserted his ghost, he would need no long reflection to discover that all these ships, these railways, these telegraphs, these factories, these printing presses, without which the whole fabric of modern English society would collapse into a mass of stagnant and starving pauperism,—that all these pillars of our State are but the ripples and the bubbles upon the surface of that great spiritual stream, the springs of which, only, he and his fellows were privileged to see; and seeing, to recognise as that which it behoved them above all things to keep pure and undefiled.

It may not be too great a flight of imagination to conceive our noble *revenant* not forgetful of the great troubles of his own day, and anxious to know how often London had been burned down since his time, and how often the plague had carried off its thousands. He would have to learn that, although London contains tenfold the inflammable matter that it did in 1666; though, not content with filling our rooms with woodwork and light draperies, we must needs lead inflammable and explosive gases into every corner of our streets and houses, we never allow even a street to burn down. And if he asked how this had come about, we should have to explain that the improvement of natural knowledge has furnished us with dozens of machines for throwing water upon fires, any one of which would have furnished the ingenious Mr. Hooke, the first "curator and experimenter" of the Royal Society, with ample materials for discourse before half a dozen meetings of that body; and that, to say truth, except for the progress of natural knowledge, we should not have been able to make even the tools by which these machines are constructed. And, further, it would be necessary to add, that although severe fires sometimes occur and inflict great damage, the loss is very generally compensated by societies, the operations of which have been rendered possible only by the progress of natural knowledge in the direction of mathematics, and the accumulation of wealth in virtue of other natural knowledge.

But the plague? My Lord Brouncker's observation would not, I fear, lead him to think that Englishmen of the nineteenth century are purer in life, or more fervent in religious faith, than the generation which could produce a Boyle, an Evelyn, and a

Milton. He might find the mud of society at the bottom instead of at the top, but I fear that the sum total would be as deserving of swift judgment as at the time of the Restoration. And it would be our duty to explain once more, and this time not without shame, that we have no reason to believe that it is the improvement of our faith, nor that of our morals, which keeps the plague from our city; but, again, that it is the improvement of our natural knowledge.

We have learned that pestilences will only take up their abode among those who have prepared unswept and ungarnished residences for them. Their cities must have narrow, unwatered streets, foul with accumulated garbage. Their houses must be ill-drained, ill-lighted, ill-ventilated. Their subjects must be ill-washed, ill-fed, ill-clothed. The London of 1665 was such a city. The cities of the East, where plague has an enduring dwelling, are such cities. We, in later times, have learned somewhat of nature, and partly obey her. Because of this partial improvement of our natural knowledge and of that fractional obedience, we have no plague; because that knowledge is still very imperfect and that obedience yet incomplete, typhus is our companion and cholera our visitor; but it is not presumptuous to express the belief that, when our knowledge is more complete and our obedience the expression of our knowledge, London will count her centuries of freedom from typhus and cholera, as she now gratefully reckons her two hundred years of ignorance of that plague, which swooped upon her thrice in the first half of the seventeenth century.

Surely, there is nothing in these explanations which is not fully borne out by the facts? Surely, the principles involved in them are now admitted among the fixed beliefs of all thinking men? Surely, it is true that our countrymen are less subject to fire, famine, pestilence, and all the evils which result from a want of command over and due anticipation of the course of nature, than were the countrymen of Milton; and health, wealth, and well-being are more abundant with us than with them? But no less certainly is the difference due to the improvement of our knowledge of nature, and the extent to which that improved knowledge has been incorporated with the household words of men, and has supplied the springs of their daily actions.

Granting for a moment, then, the truth of that which the depreciators of natural knowledge are so fond of urging, that its

improvement can only add to the resources of our material civilisation; admitting it to be possible that the founders of the Royal Society themselves looked for no other reward than this, I cannot confess that I was guilty of exaggeration when I hinted, that to him who had the gift of distinguishing between prominent events and important events, the origin of a combined effort on the part of mankind to improve natural knowledge might have loomed larger than the Plague and have out-shone the glare of the Fire; as a something fraught with a wealth of beneficence to mankind, in comparison with which the damage done by those ghastly evils would shrink into insignificance.

It is very certain that for every victim slain by the plague, hundreds of mankind exist and find a fair share of happiness in the world by the aid of the spinning jenny. And the great fire, at its worst, could not have burned the supply of coal, the daily working of which, in the bowels of the earth, made possible by the steam pump, gives rise to an amount of wealth to which the millions lost in old London are but as an old song.

But spinning jenny and steam pump are, after all, but toys, possessing an accidental value; and natural knowledge creates multitudes of more sub le contrivances, the praises of which do not happen to be sung because they are not directly convertible into instruments for creating wealth. When I contemplate natural knowledge squandering such gifts among men, the only appropriate comparison I can find for her is, to liken her to such a peasant woman as one sees in the Alps, striding ever upward, heavily burdened, and with mind bent only on her home; but yet, without effort and without thought, knitting for her children. Now stockings are good and comfortable things, and the children will undoubtedly be much the better for them; but surely it would be short-sighted, to say the least of it, to depreciate this toiling mother as a mere stocking-machine—a mere provider of physical comforts?

However, there are blind leaders of the blind, and not a few of them, who take this view of natural knowledge, and can see nothing in the bountiful mother of humanity but a sort of comfort-grinding machine. According to them, the improvement of natural knowledge always has been, and always must be, synonymous with no more than the improvement of the material resources and the increase of the gratifications of men.

Natural knowle ge is, in their eyes, no real mother of mankind,

bringing them up with kindness, and, if need be, with sternness, in the way they should go, and instructing them in all things needful for their welfare; but a sort of fairy god-mother, ready to furnish her pets with shoes of swiftness, swords of sharpness, and omnipotent Aladdin's lamps, so that they may have telegraphs to Saturn, and see the other side of the moon, and thank God they are better than their benighted ancestors.

If this talk were true, I, for one, should not greatly care to toil in the service of natural knowledge. I think I would just as soon be quietly chipping my own flint axe, after the manner of my forefathers a few thousand years back, as be troubled with the endless malady of thought which now infests us all, for such reward. But I venture to say that such views are contrary alike to reason and to fact. Those who discourse in such fashion seem to me to be so intent upon trying to see what is above nature, or what is behind her, that they are blind to what stares them in the face, in her.

I should not venture to speak thus strongly if my justification were not to be found in the simplest and most obvious facts,—if it needed more than an appeal to the most notorious truths to justify my assertion, that the improvement of natural knowledge, whatever direction it has taken, and however low the aims of those who may have commenced it—has not only conferred practical benefits on men, but, in so doing, has effected a revolution in their conceptions of the universe and of themselves, and has profoundly altered their modes of thinking and their views of right and wrong. I say that natural knowledge, seeking to satisfy natural wants, has found the ideas which can alone still spiritual cravings I say that natural knowledge, in desiring to ascertain the laws of comfort, has been driven to discover those of conduct, and to lay the foundations of a new morality.

Let us take these points separately; and, first, what great ideas has natural knowledge introduced into men's minds?

I cannot but think that the foundations of all natural knowledge were laid when the reason of man first came face to face with the facts of nature; when the savage first learned that the fingers of one hand are fewer than those of both; that it is shorter to cross a stream than to head it; that a stone stops where it is unless it be moved, and that it drops from the hand which lets it go; that light and heat come and go with the sun; that sticks burn away in a fire; that plants and animals grow

and die; that if he struck his fellow savage a blow he would make him angry, and perhaps get a blow in return; while if he offered him a fruit he would please him, and perhaps receive a fish in exchange. When men had acquired this much knowledge, the outlines, rude though they were, of mathematics, of physics, of chemistry, of biology, of moral, economical, and political science, were sketched. Nor did the germ of religion fail when science began to bud. Listen to words which, though new, are yet three thousand years old:—

> " . . . When in heaven the stars about the moon
> Look beautiful, when all the winds are laid,
> And every height comes out, and jutting peak
> And valley, and the immeasurable heavens
> Break open to their highest, and all the stars
> Shine, and the shepherd gladdens in his heart." [1]

But if the half-savage Greek could share our feelings thus far, it is irrational to doubt that he went further, to find, as we do, that upon that brief gladness there follows a certain sorrow,—the little light of awakened human intelligence shines so mere a spark amidst the abyss of the unknown and unknowable; seems so insufficient to do more than illuminate the imperfections that cannot be remedied, the aspirations that cannot be realised, of man's own nature. But in this sadness, this consciousness of the limitation of man, this sense of an open secret which he cannot penetrate, lies the essence of all religion; and the attempt to embody it in the forms furnished by the intellect is the origin of the higher theologies.

Thus it seems impossible to imagine but that the foundations of all knowledge—secular or sacred—were laid when intelligence dawned, though the superstructure remained for long ages so slight and feeble as to be compatible with the existence of almost any general view respecting the mode of governance of the universe. No doubt, from the first, there were certain phænomena which, to the rudest mind, presented a constancy of occurrence, and suggested that a fixed order ruled, among them at any rate. I doubt if the grossest of Fetish worshippers ever imagined that a stone must have a god within it to make it fall, or that a fruit had a god within it to make it taste sweet. With regard to such matters as these, it is hardly questionable that mankind from the first took strictly positive and scientific views.

But, with respect to all the less familiar occurrences which

[1] Need it be said that this is Tennyson's English for Homer's Greek?

present themselves, uncultured man, no doubt, has always taken himself as the standard of comparison, as the centre and measure of the world; nor could he well avoid doing so. And finding that his apparently uncaused will has a powerful effect in giving rise to many occurrences, he naturally enough ascribed other and greater events to other and greater volitions, and came to look upon the world and all that therein is, as the product of the volitions of persons like himself, but stronger, and capable of being appeased or angered, as he himself might be soothed or irritated. Through such conceptions of the plan and working of the universe all mankind have passed, or are passing. And we may now consider what has been the effect of the improvement of natural knowledge on the views of men who have reached this stage, and who have begun to cultivate natural knowledge with no desire but that of "increasing God's honour and bettering man's estate."

For example: what could seem wiser, from a mere material point of view, more innocent from a theological one, to an ancient people, than that they should learn the exact succession of the seasons, as warnings for their husbandmen; or the position of the stars, as guides to their rude navigators? But what has grown out of this search for natural knowledge of so merely useful a character? You all know the reply. Astronomy,—which of all sciences has filled men's minds with general ideas of a character most foreign to their daily experience, and has, more than any other, rendered it impossible for them to accept the beliefs of their fathers. Astronomy,—which tells them that this so vast and seemingly solid earth is but an atom among atoms, whirling, no man knows whither, through illimitable space; which demonstrates that what we call the peaceful heaven above us, is but that space, filled by an infinitely subtle matter whose particles are seething and surging, like the waves of an angry sea; which opens up to us infinite regions where nothing is known, or ever seems to have been known, but matter and force, operating according to rigid rules; which leads us to contemplate phænomena the very nature of which demonstrates that they must have had a beginning, and that they must have an end, but the very nature of which also proves that the beginning was, to our conceptions of time, infinitely remote, and that the end is as immeasurably distant.

But it is not alone those who pursue astronomy who ask for bread and receive ideas. What more harmless than the attempt

to lift and distribute water by pumping it; what more absolutely and grossly utilitarian? But out of pumps grew the discussions about nature's abhorrence of a vacuum; and then it was discovered that nature does not abhor a vacuum, but that air has weight; and that notion paved the way for the doctrine that all matter has weight, and that the force which produces weight is co-extensive with the universe,—in short, to the theory of universal gravitation and endless force. And learning how to handle gases led to the discovery of oxygen and to modern chemistry, and to the notion of the indestructibility of matter.

Again, what simpler, or more absolutely practical, than the attempt to keep the axle of a wheel from heating when the wheel turns round very fast? How useful for carters and gig drivers to know something about this; and how good were it, if any ingenious person would find out the cause of such phænomena, and thence educe a general remedy for them. Such an ingenious person was Count Rumford; and he and his successors have landed us in the theory of the persistence or indestructibility of force. And in the infinitely minute, as in the infinitely great, the seekers after natural knowledge of the kinds called physical and chemical, have everywhere found a definite order and succession of events which seem never to be infringed.

And how has it fared with "Physick" and Anatomy? Have the anatomist, the physiologist, or the physician, whose business it has been to devote themselves assiduously to that eminently practical and direct end, the alleviation of the sufferings of mankind,—have they been able to confine their vision more absolutely to the strictly useful? I fear they are the worst offenders of all. For if the astronomer has set before us the infinite magnitude of space, and the practical eternity of the duration of the universe; if the physical and chemical philosophers have demonstrated the infinite minuteness of its constituent parts, and the practical eternity of matter and of force; and if both have alike proclaimed the universality of a definite and predicable order and succession of events, the workers in biology have not only accepted all these, but have added more startling theses of their own. For, as the astronomers discover in the earth no centre of the universe, but an eccentric speck, so the naturalists fi.d man to be no centre of the living world, but one amidst endless modifications of life; and as the astronomer observes the mark of practically endless time set upon the arrangements of the solar system, so the student of life finds the records of ancient forms of existence peopling the

world for ages, which, in relation to human experience, are infinite.

Furthermore, the physiologist finds life to be as dependent for its manifestation on particular molecular arrangements as any physical or chemical phenomenon; and, wherever he extends his researches, fixed order and unchanging causation reveal themselves, as plainly as in the rest of nature.

Nor can I find that any other fate has awaited the germ of Religion. Arising, like all other kinds of knowledge, out of the action and interaction of man's mind, with that which is not man's mind, it has taken the intellectual coverings of Fetishism or Polytheism; of Theism or Atheism; of Superstition or Rationalism. With these, and their relative merits and demerits I have nothing to do; but this it is needful for my purpose to say, that if the religion of the present differs from that of the past, it is because the theology of the present has become more scientific than that of the past; because it has not only renounced idols of wood and idols of stone, but begins to see the necessity of breaking in pieces the idols built up of books and traditions and fine-spun ecclesiastical cobwebs: and of cherishing the noblest and most human of man's emotions, by worship "for the most part of the silent sort" at the altar of the Unknown and Unknowable.

Such are a few of the new conceptions implanted in our minds by the improvement of natural knowledge. Men have acquired the ideas of the practically infinite extent of the universe and of its practical eternity; they are familiar with the conception that our earth is but an infinitesimal fragment of that part of the universe which can be seen; and that, nevertheless, its duration is, as compared with our standards of time, infinite. They have further acquired the idea that man is but one of innumerable forms of life now existing on the globe, and that the present existences are but the last of an immeasurable series of predecessors. Furthermore, every step they have made in natural knowledge has tended to extend and rivet in their minds the conception of a definite order of the universe—which is embodied in what are called, by an unhappy metaphor, the laws of nature—and to narrow the range and loosen the force of men's belief in spontaneity, or in changes other than such as arise out of that definite order itself.

Whether these ideas are well or ill founded is not the question. No one can deny that they exist, and have been the inevitable outgrowth of the improvement of natural knowledge. And if

so, it cannot be doubted that they are changing the form of men's most cherished and most important convictions.

And as regards the second point—the extent to which the improvement of natural knowledge has remodelled and altered what may be termed the intellectual ethics of men—what are among the moral convictions most fondly held by barbarous and semi-barbarous people.

They are the convictions that authority is the soundest basis of belief; that merit attaches to a readiness to believe; that the doubting disposition is a bad one, and scepticism a sin; that when good authority has pronounced what is to be believed, and faith has accepted it, reason has no further duty. There are many excellent persons who yet hold by these principles, and it is not my present business, or intention, to discuss their views. All I wish to bring clearly before your minds is the unquestionable fact that the improvement of natural knowledge is effected by methods which directly give the lie to all these convictions, and assume the exact reverse of each to be true.

The improver of natural knowledge absolutely refuses to acknowledge authority, as such. For him, scepticism is the highest of duties; blind faith the one unpardonable sin. And it cannot be otherwise, for every great advance in natural knowledge has involved the absolute rejection of authority, the cherishing of the keenest scepticism, the annihilation of the spirit of blind faith; and the most ardent votary of science holds his firmest convictions, not because the men he most venerates hold them; not because their verity is testified by portents and wonders; but because his experience teaches him that whenever he chooses to bring these convictions into contact with their primary source, nature—whenever he thinks fit to test them by appealing to experiment and to observation—nature will confirm them. The man of science has learned to believe in justification, not by faith, but by verification.

Thus, without for a moment pretending to despise the practical results of the improvement of natural knowledge, and its beneficial influence on material civilisation, it must, I think, be admitted that the great ideas, some of which I have indicated, and the ethical spirit which I have endeavoured to sketch, in the few moments which remained at my disposal, constitute the real and permanent significance of natural knowledge.

If these ideas be destined, as I believe they are, to be more and more firmly established as the world grows older; if that spirit be fated, as I believe it is, to extend itself into all departments of human thought, and to become co-extensive with the range of knowledge; if, as our race approaches its maturity, it discovers, as I believe it will, that there is but one kind of knowledge and but one method of acquiring it; then we, who are still children, may justly feel it our highest duty to recognise the advisableness of improving natural knowledge, and so to aid ourselves and our successors in our course towards the noble goal which lies before mankind.

A LIBERAL EDUCATION; AND WHERE TO FIND IT

The business which the South London Working Men's College has undertaken is a great work; indeed, I might say, that Education, with which that college proposes to grapple, is the greatest work of all those which lie ready to a man's hand just at present.

And, at length, this fact is becoming generally recognised. You cannot go anywhere without hearing a buzz of more or less confused and contradictory talk on this subject—nor can you fail to notice that, in one point at any rate, there is a very decided advance upon like discussions in former days. Nobody outside the agricultural interest now dares to say that education is a bad thing. If any representative of the once large and powerful party, which, in former days, proclaimed this opinion, still exists in a semi-fossil state, he keeps his thoughts to himself. In fact, there is a chorus of voices, almost distressing in their harmony, raised in favour of the doctrine that education is the great panacea for human troubles, and that, if the country is not shortly to go to the dogs, everybody must be educated.

The politicians tell us, "you must educate the masses because they are going to be masters." The clergy join in the cry for education, for they affirm that the people are drifting away from church and chapel into the broadest infidelity. The manufacturers and the capitalists swell the chorus lustily. They declare that ignorance makes bad workmen; that England will soon be unable to turn out cotton goods, or steam engines, cheaper than other people; and then, Ichabod! Ichabod! the glory will be departed from us. And a few voices are lifted up in favour of the doctrine that the masses should be educated because they are men and women with unlimited capacities of being, doing, and suffering, and that it is as true now, as ever it was, that the people perish for lack of knowledge.

These members of the minority, with whom I confess I have a good deal of sympathy, are doubtful whether any of the other reasons urged in favour of the education of the people are of much

value—whether, indeed, some of them are based upon either wise or noble grounds of action. They question if it be wise to tell people that you will do for them, out of fear of their power, what you have left undone, so long as your only motive was compassion for their weakness and their sorrows. And if ignorance of everything which it is needful a ruler should know is likely to do so much harm in the governing classes of the future, why is it, they ask reasonably enough, that such ignorance in the governing classes of the past has not been viewed with equal horror?

Compare the average artisan and the average country squire, and it may be doubted if you will find a pin to choose between the two in point of ignorance, class feeling, or prejudice. It is true that the ignorance is of a different sort—that the class feeling is in favour of a different class—and that the prejudice has a distinct savour of wrong-headedness in each case—but it is questionable if the one is either a bit better, or a bit worse, than the other. The old protectionist theory is the doctrine of trades unions as applied by the squires, and the modern trades unionism is the doctrine of the squires applied by the artisans. Why should we be worse off under one *régime* than under the other?

Again, this sceptical minority asks the clergy to think whether it is really want of education which keeps the masses away from their ministrations—whether the most completely educated men are not as open to reproach on this score as the workmen; and whether, perchance, this may not indicate that it is not education which lies at the bottom of the matter?

Once more, these people, whom there is no pleasing, venture to doubt whether the glory, which rests upon being able to undersell all the rest of the world, is a very safe kind of glory—whether we may not purchase it too dear; especially if we allow education, which ought to be directed to the making of men, to be diverted into a process of manufacturing human tools, wonderfully adroit in the exercise of some technical industry, but good for nothing else.

And, finally, these people inquire whether it is the masses alone who need a reformed and improved education. They ask whether the richest of our public schools might not well be made to supply knowledge, as well as gentlemanly habits, a strong class feeling, and eminent proficiency in cricket. They seem to think that the noble foundations of our old universities are hardly fulfilling their functions in their present posture of

half-clerical seminaries, half racecourses, where men are trained to win a senior wranglership, or a double-first, as horses are trained to win a cup, with as little reference to the needs of after-life in the case of the man as in that of the racer. And while as zealous for education as the rest, they affirm that if the education of the richer classes were such as to fit them to be the leaders and the governors of the poorer; and if the education of the poorer classes were such as to enable them to appreciate really wise guidance and good governance, the politicians need not fear mob-law, nor the clergy lament their want of flocks, nor the capitalists prognosticate the annihilation of the prosperity of the country.

Such is the diversity of opinion upon the why and the wherefore of education. And my hearers will be prepared to expect that the practical recommendations which are put forward are not less discordant. There is a loud cry for compulsory education. We English, in spite of constant experience to the contrary, preserve a touching faith in the efficacy of acts of parliament; and I believe we should have compulsory education in the course of next session if there were the least probability that half a dozen leading statesmen of different parties would agree what that education should be.

Some hold that education without theology is worse than none. Others maintain, quite as strongly, that education with theology is in the same predicament. But this is certain, that those who hold the first opinion can by no means agree what theology should be taught; and that those who maintain the second are in a small minority.

At any rate "make people learn to read, write, and cipher," say a great many; and the advice is undoubtedly sensible as far as it goes. But, as has happened to me in former days, those who, in despair of getting anything better, advocate this measure, are met with the objection that it is very like making a child practise the use of a knife, fork, and spoon, without giving it a particle of meat. I really don't know what reply is to be made to such an objection.

But it would be unprofitable to spend more time in disentangling, or rather in showing up the knots in, the ravelled skeins of our neighbours. Much more to the purpose is it to ask if we possess any clue of our own which may guide us among these entanglements. And by way of a beginning, let us ask ourselves—What is education? Above all things, what is our

ideal of a thoroughly liberal education?—of that education which, if we could begin life again, we would give ourselves—of that education which, if we could mould the fates to our own will, we would give our children? Well, I know not what may be your conceptions upon this matter, but I will tell you mine, and I hope I shall find that our views are not very discrepant.

Suppose it were perfectly certain that the life and fortune of every one of us would, one day or other, depend upon his winning or losing a game at chess. Don't you think that we should all consider it to be a primary duty to learn at least the names and the moves of the pieces; to have a notion of a gambit, and a keen eye for all the means of giving and getting out of check? Do you not think that we should look with a disapprobation amounting to scorn, upon the father who allowed his son, or the state which allowed its members, to grow up without knowing a pawn from a knight?

Yet, it is a very plain and elementary truth that the life, the fortune, and the happiness of every one of us, and, more or less, of those who are connected with us, do depend upon our knowing something of the rules of a game infinitely more difficult and complicated than chess. It is a game which has been played for untold ages, every man and woman of us being one of the two players in a game of his or her own. The chess-board is the world, the pieces are the phenomena of the universe, the rules of the game are what we call the laws of nature. The player on the other side is hidden from us. We know that his play is always fair, just, and patient. But also we know, to our cost that he never overlooks a mistake, or makes the smallest allowance for ignorance. To the man who plays well, the highest stakes are paid, with that sort of overflowing generosity with which the strong shows delight in strength. And one who plays ill is checkmated—without haste, but without remorse.

My metaphor will remind some of you of the famous picture in which Retzsch has depicted Satan playing at chess with man for his soul. Substitute for the mocking fiend in that picture a calm, strong angel who is playing for love, as we say, and would rather lose than win—and I should accept it as an image of human life.

Well, what I mean by Education is learning the rules of this mighty game. In other words, education is the instruction of the intellect in the laws of nature, under which name I include not merely things and their forces, but men and their ways;

and the fashioning of the affections and of the will into an earnest and loving desire to move in harmony with those laws. For me, education means neither more nor less than this. Anything which professes to call itself education must be tried by this standard, and if it fails to stand the test, I will not call it education, whatever may be the force of authority or of numbers upon the other side.

It is important to remember that, in strictness, there is no such thing as an uneducated man. Take an extreme case. Suppose that an adult man, in the full vigour of his faculties, could be suddenly placed in the world, as Adam is said to have been, and then left to do as he best might. How long would he be left uneducated? Not five minutes. Nature would begin to teach him, through the eye, the ear, the touch, the properties of objects. Pain and pleasure would be at his elbow telling him to do this and avoid that; and by slow degrees the man would receive an education which, if narrow, would be thorough, real, and adequate to his circumstances, though there would be no extras and very few accomplishments.

And if to this solitary man entered a second Adam, or, better still, an Eve, a new and greater world, that of social and moral phenomena, would be revealed. Joys and woes, compared with which all others might seem but faint shadows, would spring from the new relations. Happiness and sorrow would take the place of the coarser monitors, pleasure and pain; but conduct would still be shaped by the observation of the natural consequences of actions; or, in other words, by the laws of the nature of man.

To every one of us the world was once as fresh and new as to Adam. And then, long before we were susceptible of any other mode of instruction, nature took us in hand, and every minute of waking life brought its educational influence, shaping our actions into rough accordance with nature's laws, so that we might not be ended untimely by too gross disobedience. Nor should I speak of this process of education as past, for any one, be he as old as he may. For every man the world is as fresh as it was at the first day, and as full of untold novelties for him who has the eyes to see them. And nature is still continuing her patient education of us in that great university, the universe, of which we are all members—nature having no Test-Acts.

Those who take honours in nature's university, who learn the laws which govern men and things and obey them, are the really

great and successful men in this world. The great mass of mankind are the "Poll," who pick up just enough to get through without much discredit. Those who won't learn at all are plucked; and then you can't come up again. Nature's pluck means extermination.

Thus the question of compulsory education is settled so far as nature is concerned. Her bill on that question was framed and passed long ago. But, like all compulsory legislation, that of nature is harsh and wasteful in its operation. Ignorance is visited as sharply as wilful disobedience—incapacity meets with the same punishment as crime. Nature's discipline is not even a word and a blow, and the blow first; but the blow without the word. It is left to you to find out why your ears are boxed.

The object of what we commonly call education—that education in which man intervenes and which I shall distinguish as artificial education—is to make good these defects in nature's methods; to prepare the child to receive nature's education, neither incapably nor ignorantly, nor with wilful disobedience; and to understand the preliminary symptoms of her pleasure, without waiting for the box on the ear. In short, all artificial education ought to be an anticipation of natural education. And a liberal education is an artificial education—which has not only prepared a man to escape the great evils of disobedience to natural laws, but has trained him to appreciate and to seize upon the rewards which nature scatters with as free a hand as her penalties.

That man, I think, has had a liberal education who has been so trained in youth that his body is the ready servant of his will, and does with ease and pleasure all the work that, as a mechanism, it is capable of; whose intellect is a clear, cold, logic engine, with all its parts of equal strength, and in smooth working order; ready, like a steam engine, to be turned to any kind of work, and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with a knowledge of the great and fundamental truths of nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions are trained to come to heel by a vigorous will, the servant of a tender conscience; who has learned to love all beauty, whether of nature or of art, to hate all vileness, and to respect others as himself.

Such an one and no other, I conceive, has had a liberal education; for he is, as completely as a man can be, in harmony with nature. He will make the best of her, and she of him. They will

get on together rarely; she as his ever beneficent mother; he as her mouthpiece, her conscious self, her minister and interpreter.

Where is such an education as this to be had? Where is there any approximation to it? Has any one tried to found such an education? Looking over the length and breadth of these islands, I am afraid that all these questions must receive a negative answer. Consider our primary schools and what is taught in them. A child learns:—

1. To read, write, and cipher, more or less well; but in a very large proportion of cases not so well as to take pleasure in reading, or to be able to write the commonest letter properly.

2. A quantity of dogmatic theology, of which the child, nine times out of ten, understands next to nothing.

3. Mixed up with this, so as to seem to stand or fall with it, a few of the broadest and simplest principles of morality. This is, to my mind, much as if a man of science should make the story of the fall of the apple in Newton's garden an integral part of the doctrine of gravitation, and teach it as of equal authority with the law of the inverse squares.

4. A good deal of Jewish history and Syrian geography, and perhaps a little something about English history and the geography of the child's own country. But I doubt if there is a primary school in England in which hangs a map of the hundred in which the village lies, so that the children may be practically taught by it what a map means.

5. A certain amount of regularity, attentive obedience, respect for others: obtained by fear, if the master be incompetent or foolish; by love and reverence, if he be wise.

So far as this school course embraces a training in the theory and practice of obedience to the moral laws of nature, I gladly admit, not only that it contains a valuable educational element, but that, so far, it deals with the most valuable and important part of all education. Yet, contrast what is done in this direction with what might be done; with the time given to matters of comparatively no importance; with the absence of any attention to things of the highest moment; and one is tempted to think of Falstaff's bill and "the halfpenny worth of bread to all that quantity of sack."

Let us consider what a child thus "educated" knows, and what it does not know. Begin with the most important topic of all—morality, as the guide of conduct. The child knows well enough that some acts meet with approbation and some with

disapprobation. But it has never heard that there lies in the nature of things a reason for every moral law, as cogent and as well defined as that which underlies every physical law; that stealing and lying are just as certain to be followed by evil consequences as putting your hand in the fire, or jumping out of a garret window. Again, though the scholar may have been made acquainted, in dogmatic fashion, with the broad laws of morality, he has had no training in the application of those laws to the difficult problems which result from the complex conditions of modern civilisation. Would it not be very hard to expect any one to solve a problem in conic sections who had merely been taught the axioms and definitions of mathematical science?

A workman has to bear hard labour, and perhaps privation, while he sees others rolling in wealth, and feeding their dogs with what would keep his children from starvation. Would it not be well to have helped that man to calm the natural promptings of discontent by showing him, in his youth, the necessary connection of the moral law which prohibits stealing with the stability of society—by proving to him, once for all, that it is better for his own people, better for himself, better for future generations, that he should starve than steal? If you have no foundation of knowledge or habit of thought to work upon, what chance have you of persuading a hungry man that a capitalist is not a thief "with a circumbendibus?" And if he honestly believes that, of what avail is it to quote the commandment against stealing when he proposes to make the capitalist disgorge?

Again, the child learns absolutely nothing of the history or the political organisation of his own country. His general impression is, that everything of much importance happened a very long while ago; and that the Queen and the gentlefolks govern the country much after the fashion of King David and the elders and nobles of Israel—his sole models. Will you give a man with this much information a vote? In easy times he sells it for a pot of beer. Why should he not? It is of about as much use to him as a chignon, and he knows as much what to do with it, for any other purpose. In bad times, on the contrary, he applies his simple theory of government, and believes that his rulers are the cause of his sufferings—a belief which sometimes bears remarkable practical fruits.

Least of all, does the child gather from this primary "education" of ours a conception of the laws of the physical world, or of

the relations of cause and effect therein. And this is the more to be lamented, as the poor are especially exposed to physical evils, and are more interested in removing them than any other class of the community. If any one is concerned in knowing the ordinary laws of mechanics one would think it is the hand-labourer, whose daily toil lies among levers and pulleys; or among the other implements of artisan work. And if any one is interested in the laws of health, it is the poor man, whose strength is wasted by ill-prepared food, whose health is sapped by bad ventilation and bad drainage, and half whose children are massacred by disorders which might be prevented. Not only does our present primary education carefully abstain from hinting to the poor man that some of his greatest evils are traceable to mere physical agencies, which could be removed by energy, patience, and frugality; but it does worse—it renders him, so far as it can, deaf to those who could help him, and tries to substitute an Oriental submission to what is falsely declared to be the will of God, for his natural tendency to strive after a better condition.

What wonder then if very recently an appeal has been made to statistics for the profoundly foolish purpose of showing that education is of no good—that it diminishes neither misery nor crime among the masses of mankind? I reply, why should the thing which has been called education do either the one or the other? If I am a knave or a fool, teaching me to read and write won't make me less of either one or the other—unless somebody shows me how to put my reading and writing to wise and good purposes.

Suppose any one were to argue that medicine is of no use, because it could be proved statistically that the percentage of deaths was just the same among people who had been taught how to open a medicine chest and among those who did not so much as know the key by sight. The argument is absurd; but it is not more preposterous than that against which I am contending. The only medicine for suffering, crime, and all the other woes of mankind, is wisdom. Teach a man to read and write, and you have put into his hands the great keys of the wisdom box. But it is quite another matter whether he ever opens the box or not. And he is as likely to poison as to cure himself, if, without guidance, he swallows the first drug that comes to hand. In these times a man may as well be purblind, as unable to read—lame, as unable to write. But I protest that, if I thought the alternative were a necessary one, I would rather

that the children of the poor should grow up ignorant of both these mighty arts, than that they should remain ignorant of that knowledge to which these arts are means.

It may be said that all these animadversions may apply to primary schools, but that the higher schools, at any rate, must be allowed to give a liberal education. In fact they professedly sacrifice everything else to this object.

Let us inquire into this matter. What do the higher schools, those to which the great middle class of the country sends its children, teach, over and above the instruction given in the primary schools? There is a little more reading and writing of English. But, for all that, every one knows that it is a rare thing to find a boy of the middle or upper classes who can read aloud decently, or who can put his thoughts on paper in clear and grammatical (to say nothing of good or elegant) language. The "ciphering" of the lower schools expands into elementary mathematics in the higher; into arithmetic, with a little algebra, a little Euclid. But I doubt if one boy in five hundred has ever heard the explanation of a rule of arithmetic, or knows his Euclid otherwise than by rote.

Of theology, the middle-class schoolboy gets rather less than poorer children, less absolutely and less relatively, because there are so many other claims upon his attention. I venture to say that, in the great majority of cases, his ideas on this subject when he leaves school are of the most shadowy and vague description, and associated with painful impressions of the weary hours spent in learning collects and catechism by heart.

Modern geography, modern history, modern literature; the English language as a language; the whole circle of the sciences, physical, moral, and social, are even more completely ignored in the higher than in the lower schools. Up till within a few years back, a boy might have passed through any one of the great public schools with the greatest distinction and credit, and might never so much as have heard of one of the subjects I have just mentioned. He might never have heard that the earth goes round the sun; that England underwent a great revolution in 1688, and France another in 1789; that there once lived certain notable men called Chaucer, Shakespeare, Milton, Voltaire, Goethe, Schiller. The first might be a German and the last an Englishman for anything he could tell you to the

contrary. And as for Science, the only idea the word would suggest to his mind would be dexterity in boxing.

I have said that this was the state of things a few years back, for the sake of the few righteous who are to be found among the educational cities of the plain. But I would not have you too sanguine about the result, if you sound the minds of the existing generation of public school-boys on such topics as those I have mentioned.

Now let us pause to consider this wonderful state of affairs; for the time will come when Englishmen will quote it as the stock example of the stolid stupidity of their ancestors in the nineteenth century. The most thoroughly commercial people, the greatest voluntary wanderers and colonists the world has ever seen, are precisely the middle classes of this country. If there be a people which has been busy making history on the great scale for the last three hundred years—and the most profoundly interesting history—history which, if it happened to be that of Greece or Rome, we should study with avidity—it is the English. If there be a people which, during the same period, has developed a remarkable literature, it is our own. If there be a nation whose prosperity depends absolutely and wholly upon their mastery over the forces of nature, upon their intelligent apprehension of, and obedience to the laws of the creation and distribution of wealth, and of the stable equilibrium of the forces of society, it is precisely this nation. And yet this is what these wonderful people tell their sons:—"At the cost of from one to two thousand pounds of our hard-earned money we devote twelve of the most precious years of your lives to school. There you shall toil, or be supposed to toil; but there you shall not learn one single thing of all those you will most want to know directly you leave school and enter upon the practical business of life. You will in all probability go into business, but you shall not know where or how any article of commerce is produced, or the difference between an export or an import, or the meaning of the word "capital." You will very likely settle in a colony, but you shall not know whether Tasmania is part of New South Wales, or *vice versâ*.

"Very probably you may become a manufacturer, but you shall not be provided with the means of understanding the working of one of your own steam-engines, or the nature of the raw products you employ; and when you are asked to buy a patent you shall not have the slightest means of judging whether

the inventor is an impostor who is contravening the elementary principles of science, or a man who will make you as rich as Crœsus.

"You will very likely get into the House of Commons. You will have to take your share in making laws which may prove a blessing or a curse to millions of men. But you shall not hear one word respecting the political organisation of your country; the meaning of the controversy between freetraders and protectionists shall never have been mentioned to you; you shall not so much as know that there are such things as economical laws.

"The mental power which will be of most importance in your daily life will be the power of seeing things as they are without regard to authority; and of drawing accurate general conclusions from particular facts. But at school and at college you shall know of no source of truth but authority; nor exercise your reasoning faculty upon anything but deduction from that which is laid down by authority.

"You will have to weary your soul with work, and many a time eat your bread in sorrow and in bitterness, and you shall not have learned to take refuge in the great source of pleasure without alloy, the serene resting-place for worn human nature—the world of art."

Said I not rightly that we are a wonderful people? I am quite prepared to allow, that education entirely devoted to these omitted subjects might not be a completely liberal education. But is an education which ignores them all a liberal education? Nay, is it too much to say that the education which should embrace these subjects and no others would be a real education, though an incomplete one; while an education which omits them is really not an education at all, but a more or less useful course of intellectual gymnastics?

For what does the middle-class school put in the place of all these things which are left out? It substitutes what is usually comprised under the compendious title of the "classics"—that is to say, the languages, the literature, and the history of the ancient Greeks and Romans, and the geography of so much of the world as was known to these two great nations of antiquity. Now, do not expect me to depreciate the earnest and enlightened pursuit of classical learning. I have not the least desire to speak ill of such occupations, nor any sympathy with those who

run them down. On the contrary, if my opportunities had lain in that direction, there is no investigation into which I could have thrown myself with greater delight than that of antiquity.

What science can present greater attractions than philology? How can a lover of literary excellence fail to rejoice in the ancient masterpieces? And with what consistency could I, whose business lies so much in the attempt to decipher the past, and to build up intelligible forms out of the scattered fragments of long-extinct beings, fail to take a sympathetic, though an unlearned, interest in the labours of a Niebuhr, a Gibbon, or a Grote? Classical history is a great section of the palæontology of man; and I have the same double respect for it as for other kinds of palæontology—that is to say, a respect for the facts which it establishes as for all facts, and a still greater respect for it as a preparation for the discovery of a law of progress.

But if the classics were taught as they might be taught—if boys and girls were instructed in Greek and Latin, not merely as languages, but as illustrations of philological science; if a vivid picture of life on the shores of the Mediterranean two thousand years ago were imprinted on the minds of scholars; if ancient history were taught, not as a weary series of feuds and fights, but traced to its causes in such men placed under such conditions; if, lastly, the study of the classical books were followed in such a manner as to impress boys with their beauties, and with the grand simplicity of their statement of the everlasting problems of human life, instead of with their verbal and grammatical peculiarities; I still think it as little proper that they should form the basis of a liberal education for our contemporaries, as I should think it fitting to make that sort of palæontology with which I am familiar the back-bone of modern education.

It is wonderful how close a parallel to classical training could be made out of that palæontology to which I refer. In the first place I could get up an osteological primer so arid, so pedantic in its terminology, so altogether distasteful to the youthful mind, as to beat the recent famous production of the head-masters out of the field in all these excellences. Next, I could exercise my boys upon easy fossils, and bring out all their powers of memory and all their ingenuity in the application of my osteo-grammatical rules to the interpretation, or construing, of those fragments. To those who had reached the higher classes, I might supply odd bones to be built up into animals, giving great

honour and reward to him who succeeded in fabricating monsters most entirely in accordance with the rules. That would answer to verse-making and essay-writing in the dead languages.

To be sure, if a great comparative anatomist were to look at these fabrications he might shake his head, or laugh. But what then? Would such a catastrophe destroy the parallel? What, think you, would Cicero, or Horace, say to the production of the best sixth form going? And would not Terence stop his ears and run out if he could be present at an English performance of his own plays? Would Hamlet, in the mouths of a set of French actors, who should insist on pronouncing English after the fashion of their own tongue, be more hideously ridiculous?

But it will be said that I am forgetting the beauty, and the human interest, which appertain to classical studies. To this I reply that it is only a very strong man who can appreciate the charms of a landscape as he is toiling up a steep hill, along a bad road. What with short-windedness, stones, ruts, and a pervading sense of the wisdom of rest and be thankful, most of us have little enough sense of the beautiful under these circumstances. The ordinary school-boy is precisely in this case. He finds Parnassus uncommonly steep, and there is no chance of his having much time or inclination to look about him till he gets to the top. And nine times out of ten he does not get to the top.

But if this be a fair picture of the results of classical teaching at its best—and I gather from those who have authority to speak on such matters that it is so—what is to be said of classical teaching at its worst, or in other words, of the classics of our ordinary middle-class schools? [1] I will tell you. It means getting up endless forms and rules by heart. It means turning Latin and Greek into English, for the mere sake of being able to do it, and without the smallest regard to the worth, or worthlessness, of the author read. It means the learning of innumerable, not always decent, fables in such a shape that the meaning they once had is dried up into utter trash; and the only impression left upon a boy's mind is, that the people who believed such things must have been the greatest idiots the world ever saw. And it means, finally, that after a dozen years spent at this kind of work, the sufferer shall be incompetent to interpret a passage in an author he has not already got up; that he shall loathe the sight of a Greek or Latin book; and that he shall never open, or

[1] For a justification of what is here said about these schools, see that valuable book, "Essays on a Liberal Education," *passim*.

think of, a classical writer again, until, wonderful to relate, he insists upon submitting his sons to the same process.

These be your gods, O Israel! For the sake of this net result (and respectability) the British father denies his children all the knowledge they might turn to account in life, not merely for the achievement of vulgar success, but for guidance in the great crises of human existence. This is the stone he offers to those whom he is bound by the strongest and tenderest ties to feed with bread.

If primary and secondary education are in this unsatisfactory state, what is to be said to the universities? This is an awful subject, and one I almost fear to touch with my unhallowed hands; but I can tell you what those say who have authority to speak.

The Rector of Lincoln College, in his lately published valuable "Suggestions for Academical Organisation with especial reference to Oxford," tells us:—

"The colleges were, in their origin, endowments, not for the elements of a general liberal education, but for the prolonged study of special and professional faculties by men of riper age. The universities embraced both these objects. The colleges, while they incidentally aided in elementary education, were specially devoted to the highest learning. . . .

"This was the theory of the middle-age university and the design of collegiate foundations in their origin. Time and circumstances have brought about a total change. The colleges no longer promote the researches of science, or direct professional study. Here and there college walls may shelter an occasional student, but not in larger proportions than may be found in private life. Elementary teaching of youths under twenty is now the only function performed by the university, and almost the only object of college endowments. Colleges were homes for the life-study of the highest and most abstruse parts of knowledge. They have become boarding schools in which the elements of the learned languages are taught to youths." (P. 127.)

If Mr. Pattison's high position, and his obvious love and respect for his university, be insufficient to convince the outside world that language so severe is yet no more than just, the authority of the Commissioners who reported on the University of Oxford in 1850 is open to no challenge. Yet they write:—

"It is generally acknowledged that both Oxford and the country at large suffer greatly from the absence of a body of learned men devoting their lives to the cultivation of science, and to the direction of academical education.

"The fact that so few books of profound research emanate from the University of Oxford, materially impairs its character as a seat of learning, and consequently its hold on the respect of the nation."

Cambridge can claim no exemption from the reproaches addressed to Oxford. And thus there seems no escape from the admission that what we fondly call our great seats of learning are simply "boarding schools" for bigger boys; that learned men are not more numerous in them than out of them; that the advancement of knowledge is not the object of fellows of colleges; that, in the philosophic calm and meditative stillness of their greenswarded courts philosophy does not thrive, and meditation bears few fruits.

It is my good fortune to reckon amongst my friends resident members of both universities, who are men of learning and research, zealous cultivators of science, keeping before their minds a noble ideal of a university, and doing their best to make that ideal a reality; and, to me, they would necessarily typify the universities, did not the authoritative statements I have quoted compel me to believe that they are exceptional, and not representative men. Indeed, upon calm consideration, several circumstances lead me to think that the Rector of Lincoln College and the Commissioners cannot be far wrong.

I believe there can be no doubt that the foreigner who should wish to become acquainted with the scientific, or the literary, activity of modern England, would simply lose his time and his pains if he visited our universities with that object.

And, as for works of profound research on any subject, and, above all, in that classical lore for which the universities profess to sacrifice almost everything else, why, a third-rate, poverty-stricken German university turns out more produce of that kind in one year, than our vast and wealthy foundations elaborate in ten.

Ask any man who is investigating any question, profoundly and thoroughly—be it historical, philosophical, philological, physical, literary, or theological; who is trying to make himself master of any abstract subject (except, perhaps, political economy and geology, both of which are intensely Anglican

sciences), whether he is not compelled to read half a dozen times as many German as English books? And whether, of these English books, more than one in ten is the work of a fellow of a college, or a professor of an English university?

Is this from any lack of power in the English as compared with the German mind? The countrymen of Grote and of Mill, of Faraday, of Robert Brown, of Lyell, and of Darwin, to go no further back than the contemporaries of men of middle age, can afford to smile at such a suggestion. England can show now, as she has been able to show in every generation since civilisation spread over the West, individual men who hold their own against the world, and keep alive the old tradition of her intellectual eminence.

But, in the majority of cases, these men are what they are in virtue of their native intellectual force, and of a strength of character which will not recognise impediments. They are not trained in the courts of the Temple of Science, but storm the walls of that edifice in all sorts of irregular ways, and with much loss of time and power, in order to obtain their legitimate positions.

Our universities not only do not encourage such men; do not offer them positions in which it should be their highest duty to do thoroughly that which they are most capable of doing; but, as far as possible, university training shuts out of the minds of those among them, who are subjected to it, the prospect that there is anything in the world for which they are specially fitted. Imagine the success of the attempt to still the intellectual hunger of any of the men I have mentioned, by putting before him, as the object of existence, the successful mimicry of the measure of a Greek song, or the roll of Ciceronian prose. Imagine how much success would be likely to attend the attempt to persuade such men that the education which leads to perfection in such elegances is alone to be called culture, while the facts of history, the process of thought, the conditions of moral and social existence, and the laws of physical nature are left to be dealt with as they may by outside barbarians!

It is not thus that the German universities, from being beneath notice a century ago, have become what they are now—the most intensely cultivated and the most productive intellectual corporations the world has ever seen.

The student who repairs to them sees in the list of classes and of professors a fair picture of the world of knowledge. Whatever

he needs to know there is some one ready to teach him, some one competent to discipline him in the way of learning; whatever his special bent, let him but be able and diligent, and in due time he shall find distinction and a career. Among his professors he sees men whose names are known and revered throughout the civilised world; and their living example infects him with a noble ambition, and a love for the spirit of work.

The Germans dominate the intellectual world by virtue of the same simple secret as that which made Napoleon the master of old Europe. They have declared *la carrière ouverte aux talents*, and every Bursch marches with a professor's gown in his knapsack. Let him become a great scholar, or man of science, and ministers will compete for his services. In Germany they do not leave the chance of his holding the office he would render illustrious to the tender mercies of a hot canvass, and the final wisdom of a mob of country parsons.

In short, in Germany, the universities are exactly what the Rector of Lincoln and the Commissioners tell us the English universities are not; that is to say, corporations "of learned men devoting their lives to the cultivation of science, and the direction of academical education." They are not "boarding schools for youths," nor clerical seminaries; but institutions for the higher culture of men, in which the theological faculty is of no more importance or prominence than the rest; and which are truly "universities," since they strive to represent and embody the totality of human knowledge, and to find room for all forms of intellectual activity.

May zealous and clear-headed reformers like Mr. Pattison succeed in their noble endeavours to shape our universities towards some such ideal as this, without losing what is valuable and distinctive in their social tone! But until they have succeeded, a liberal education will be no more obtainable in our Oxford and Cambridge Universities than in our public schools.

If I am justified in my conception of the ideal of a liberal education; and if what I have said about the existing educational institutions of the country is also true, it is clear that the two have no sort of relation to one another; that the best of our schools and the most complete of our university trainings give but a narrow, one-sided, and essentially illiberal education—while the worst give what is really next to no education at all. The South London Working-Men's College could not copy any of these institutions if it would; I am bold enough to express the conviction that it ought not if it could.

For what is wanted is the reality and not the mere name of a liberal education; and this college must steadily set before itself the ambition to be able to give that education sooner or later. At present we are but beginning, sharpening our educational tools, as it were, and, except a modicum of physical science, we are not able to offer much more than is to be found in an ordinary school.

Moral and social science—one of the greatest and most fruitful of our future classes, I hope—at present lacks only one thing in our programme, and that is a teacher. A considerable want, no doubt; but it must be recollected that it is much better to want a teacher than to want the desire to learn.

Further, we need what, for want of a better name, I must call Physical Geography. What I mean is that which the Germans call *Erdkunde*. It is a description of the earth, of its place and relation to other bodies; of its general structure, and of its great features—winds, tides, mountains, plains; of the chief forms of the vegetable and animal worlds, of the varieties of man. It is the peg upon which the greatest quantity of useful and entertaining scientific information can be suspended.

Literature is not upon the College programme; but I hope some day to see it there. For literature is the greatest of all sources of refined pleasure, and one of the great uses of a liberal education is to enable us to enjoy that pleasure. There is scope enough for the purposes of liberal education in the study of the rich treasures of our own language alone. All that is needed is direction, and the cultivation of a refined taste by attention to sound criticism. But there is no reason why French and German should not be mastered sufficiently to read what is worth reading in those languages with pleasure and with profit.

And finally, by and by, we must have History; treated not as a succession of battles and dynasties; not as a series of biographies; not as evidence that Providence has always been on the side of either Whigs or Tories; but as the development of man in times past, and in other conditions than our own.

But, as it is one of the principles of our College to be self-supporting, the public must lead, and we must follow, in these matters. If my hearers take to heart what I have said about liberal education, they will desire these things, and I doubt not we shall be able to supply them. But we must wait till the demand is made.

ON THE METHODS AND RESULTS OF ETHNOLOGY[1]

ETHNOLOGY is the science which determines the distinctive characters of the persistent modifications of mankind; which ascertains the distribution of those modifications in present and past times, and seeks to discover the causes, or conditions of existence, both of the modifications and of their distribution. I say "persistent" modifications, because, unless incidentally, ethnology has nothing to do with chance and transitory peculiarities of human structure. And I speak of "persistent modifications" or "stocks" rather than of "varieties," or "races," or "species," because each of these last well-known terms implies, on the part of its employer, a preconceived opinion touching one of those problems, the solution of which is the ultimate object of the science; and in regard to which, therefore, ethnologists are especially bound to keep their minds open and their judgments freely balanced.

Ethnology, as thus defined, is a branch of ANTHROPOLOGY, the great science which unravels the complexities of human structure; traces out the relations of man to other animals; studies all that is especially human in the mode in which man's complex functions are performed; and searches after the conditions which have determined his presence in the world. And anthropology is a section of ZOOLOGY, which again is the anima half of BIOLOGY—the science of life and living things.

Such is the position of ethnology, such are the objects of the ethnologist. The paths or methods, by following which he may hope to reach his goal, are diverse. He may work at man from the point of view of the pure zoologist, and investigate the anatomical and physiological peculiarities of Negroes, Australians, or Mongolians, just as he would inquire into those of pointers, terriers, and turnspits—"persistent modifications" of man's almost universal companion. Or he may seek aid from researches into the most human manifestation of humanity—Language; and assuming that what is true of speech is true of

[1] "Fortnightly Review," 1865.

the speaker—a hypothesis as questionable in science as it is in ordinary life—he may apply to mankind themselves the conclusions drawn from a searching analysis of their words and grammatical forms.

Or, the ethnologist may turn to the study of the practical life of men; and relying upon the inherent conservatism and small inventiveness of untutored mankind, he may hope to discover in manners and customs, or in weapons, dwellings, and other handiwork, a clue to the origin of the resemblances and differences of nations. Or, he may resort to that kind of evidence which is yielded by History proper, and consists of the beliefs of men concerning past events, embodied in traditional, or in written, testimony. Or, when that thread breaks, Archæology, which is the interpretation of the unrecorded remains of man's works, belonging to the epoch since the world has reached its present condition, may still guide him. And, when even the dim light of archæology fades, there yet remains Palæontology, which, in these latter years, has brought to daylight once more the exuvia of ancient populations, whose world was not our world, who have been buried in river beds immemorially dry, or carried by the rush of waters into caves, inaccessible to inundation since the dawn of tradition.

Along each, or all, of these paths the ethnologist may press towards his goal; but they are not equally straight, or sure, or easy to tread. The way of palæontology has but just been laid open to us. Archæological and historical investigations are of great value for all those peoples whose ancient state has differed widely from their present condition, and who have the good or evil fortune to possess a history. But on taking a broad survey of the world, it is astonishing how few nations present either condition. Respecting five-sixths of the persistent modifications of mankind, history and archæology are absolutely silent. For half the rest, they might as well be silent for anything that is to be made of their testimony. And, finally, when the question arises as to what was the condition of mankind more than a paltry two or three thousand years ago, history and archæology are, for the most part, mere dumb dogs. What light does either of these branches of knowledge throw on the past of the man of the New World, if we except the Central Americans and the Peruvians; on that of the Africans, save those of the valley of the Nile and a fringe of the Mediterranean; on that of all the Polynesian, Australian, and central Asiatic peoples, the former

of whom probably, and the last certainly, were, at the dawn of history, substantially what they are now? While thankfully accepting what history has to give him, therefore, the ethnologist must not look for too much from her.

Is more to be expected from inquiries into the customs and handicrafts of man? It is to be feared not. In reasoning from identity of custom to identity of stock the difficulty always obtrudes itself, that the minds of men being everywhere similar, differing in quality and quantity but not in kind of faculty, like circumstances must tend to produce like contrivances; at any rate, so long as the need to be met and conquered is of a very simple kind. That two nations use calabashes or shells for drinking-vessels, or that they employ spears, or clubs, or swords and axes of stone and metal as weapons and implements, cannot be regarded as evidence that these two nations had a common origin, or even that intercommunication ever took place between them; seeing that the convenience of using calabashes or shells for such purposes, and the advantage of poking an enemy with a sharp stick, or hitting him with a heavy one, must be early forced by nature upon the mind of even the stupidest savage. And when he had found out the use of a stick, he would need no prompting to discover the value of a chipped or whetted stone, or of an angular piece of native metal, for the same object. On the other hand, it may be doubted, whether the chances are not greatly against independent peoples arriving at the manufacture of a boomerang, or of a bow; which last, if one comes to think of it, is a rather complicated apparatus; and the tracing of the distribution of inventions as complex as these, and of such strange customs as betel-chewing and tobacco-smoking, may afford valuable ethnological hints.

Since the time of Leibnitz, and guided by such men as Humboldt, Abel Remusat, and Klaproth, Philology has taken far higher ground. Thus Prichard affirms that "the history of nations, termed Ethnology, must be mainly founded on the relations of their languages."

An eminent living philologer, August Schleicher, in a recent essay, puts forward the claims of his science still more forcibly:—

"If, however, language is the human *κατ' ἐξοχήν*, the suggestion arises whether it should not form the basis of any scientific systematic arrangement of mankind; whether the foundation of the natural classification of the genus Homo has not been discovered in it.

"How little constant are cranial peculiarities and other so-called race characters! Language, on the other hand, is always a perfectly constant

diagnostic. A German may occasionally compete in hair and prognathism with a negro, but a negro language will never be his mother tongue. Of how little importance for mankind the so-called race characters are, is shown by the fact that speakers of languages belonging to one and the same linguistic family may exhibit the peculiarities of various races. Thus the settled Osmanli Turk exhibits Caucasian characters, whilst other so-called Tartaric Turks exemplify the Mongol type. On the other hand, the Magyar and the Basque do not depart in any essential physical peculiarity from the Indo-Germans, whilst the Magyar, Basque, and Indo-Germanic tongues are widely different. Apart from their inconstancy, again, the so-called race characters can hardly yield a scientifically natural system. Languages, on the other hand, readily fall into a natural arrangement, like that of which other vital products are susceptible, especially when viewed from their morphological side. . . . The externally visible structure of the cerebral and facial skeletons, and of the body generally, is less important than that no less material but infinitely more delicate corporeal structure, the function of which is speech. I conceive, therefore, that the natural classification of languages is also the natural classification of mankind. With language, moreover, all the higher manifestations of man's vital activity are closely interwoven, so that these receive due recognition in and by that of speech." [1]

Without the least desire to depreciate the value of philology as an adjuvant to ethnology, I must venture to doubt, with Rudolphi, Desmoulins, Crawfurd, and others, its title to the leading position claimed for it by the writers whom I have just quoted. On the contrary, it seems to me obvious that, though, in the absence of any evidence to the contrary, unity of languages may afford a certain presumption in favour of the unity of stock of the peoples speaking those languages, it cannot be held to prove that unity of stock, unless philologers are prepared to demonstrate, that no nation can lose its language and acquire that of a distinct nation, without a change of blood corresponding with the change of language. Desmoulins long ago put this argument exceedingly well:—

"Let us imagine the recurrence of one of those slow, or sudden, political revolutions, or say of those secular changes which among different people and at different epochs have annihilated historical monuments and even extinguished tradition. In that case, the evidence, now so clear, that the negroes of Hayti were slaves imported by a French colony, who, by the very effect of the subordination involved in slavery lost their own diverse languages and adopted that of their masters, would vanish. And metaphysical philosophers, observing the identity of Haytian French with that spoken on the shores of the Seine and the Loire, would argue that the men of St. Domingo, with woolly heads, black and oily skins, small calves, and slightly bent knees, are of the same race, descended from the same parental stock, as the Frenchmen with silky brown, chestnut, or fair hair, and white skins. For they would say, their languages are more similar than French is to German or Spanish." [2]

[1] August Schleicher. Ueber die Bedeutung der Sprache für die Naturgeschichte des Menschen, pp. 16-18. Weimar, 1858.

[2] Desmoulins, "Histoire Naturelle des Races Humaines, p. 345, 1826.

It must not be imagined that the case put by Desmoulins is a merely hypothetical one. Events precisely similar to the transport of a body of Africans to the West India Islands, indeed, cannot have happened among uncivilised races, but similar results have followed the importation of bodies of conquerors among an enslaved people over and over again. There is hardly a country in Europe in which two or more nations speaking widely different tongues have not become intermixed; and there is hardly a language of Europe of which we have any right to think that its structure affords a just indication of the amount of that intermixture.

As Dr. Latham has well said:—

"It is certain that the language of England is of Anglo-Saxon origin, and that the remains of the original Keltic are unimportant. It is by no means so certain that the blood of Englishmen is equally Germanic. A vast amount of Kelticism, not found in our tongue, very probably exists in our pedigrees. The ethnology of France is still more complicated. Many writers make the Parisian a Roman on the strength of his language; whilst others make him a Kelt on the strength of certain moral characteristics, combined with the previous Kelticism of the original Gauls. Spanish and Portuguese, as languages, are derivations from the Latin; Spain and Portugal, as countries, are Iberic, Latin, Gothic, and Arab, in different proportions. Italian is modern Latin all the world over; yet surely there must be much Keltic blood in Lombardy, and much Etruscan intermixture in Tuscany.

"In the ninth century every man between the Elbe and the Niemen spoke some Slavonic dialect; they now nearly all speak German. Surely the blood is less exclusively Gothic than the speech." [1]

In other words, what philologer, if he had nothing but the vocabulary and grammar of the French and English languages to guide him, would dream of the real causes of the unlikeness of a Norman to a Provençal, of an Orcadian to a Cornishman? How readily might he be led to suppose that the different climatal conditions to which these speakers of one tongue have so long been exposed, have caused their physical differences; and how little would he suspect that these are due (as we happen to know they are) to wide differences of blood.

Few take duly into account the evidence which exists as to the ease with which unlettered savages gain or lose a language. Captain Erskine, in his interesting "Journal of a Cruise among the Islands of the Western Pacific," especially remarks upon the "avidity with which the inhabitants of the polyglot islands of Melanesia, from New Caledonia to the Solomon Islands, adopt the improvements of a more perfect language than their own,

[1] Latham, "Man and his Migrations," p. 171.

which different causes and accidental communication still continue to bring to them;" and he adds that "among the Melanesian islands scarcely one was found by us which did not possess, in some cases still imperfectly, the decimal system of numeration in addition to their own, in which they reckon only to five."

Yet how much philological reasoning in favour of the affinity or diversity of two distinct peoples has been based on the mere comparison of numerals!

But the most instructive example of the fallacy which may attach to merely philological reasonings, is that afforded by the Feejeans, who are, physically, so intimately connected with the adjacent Negritos of New Caledonia, etc., that no one can doubt to what stock they belong, and who yet, in the form and substance of their language, are Polynesian. The case is as remarkable as if the Canary Islands should have been found to be inhabited by negroes speaking Arabic, or some other clearly Semitic dialect, as their mother tongue. As it happens, the physical peculiarities of the Feejeans are so striking, and the conditions under which they live are so similar to those of the Polynesians, that no one has ventured to suggest that they are merely modified Polynesians—a suggestion which could otherwise certainly have been made. But if languages may be thus transferred from one stock to another, without any corresponding intermixture of blood, what ethnological value has philology?—what security does unity of language afford us that the speakers of that language may not have sprung from two, or three, or a dozen, distinct sources?

Thus we come, at last, to the purely zoological method, from which it is not unnatural to expect more than from any other, seeing that, after all, the problems of ethnology are simply those which are presented to the zoologist by every widely distributed animal he studies. The father of modern zoology seems to have had no doubt upon this point. At the twenty-eighth page of the standard twelfth edition of the "Systema Naturæ," in fact, we find:—

I. PRIMATES.

Dentes primores incisores : superiores IV. paralleli, mammæ pectorales II.

1. HOMO.	Nosce te ipsum.
Sapiens.	1. H. diurnus: *varians cultura, loco.*
Ferus.	Tetrapus, mutus, hirsutus.

. . . .

Americanus	α.	Rufus, cholericus, rectus—*Pilis* nigris, rectis, crassis—*Naribus* patulis—*Facie* ephelitica: *Mento* subimberbi. *Pertinax*, contentus, liber. *Pingit* se lineis dædaleis rubris. *Regitur* Consuetudine.
Europæus	β.	Albus sanguineus torosus. *Pilis* flavescentibus, prolixis. *Oculis* cœruleis. *Levis*, argutus, inventor. *Tegitur* Vestimentis arctis. *Regitur* Ritibus.
Asiaticus	γ.	Luridus, melancholicus, rigidus. *Pilis* nigricantibus. *Oculis* fuscis. *Severus*, fastuosus, avarus. *Tegitur* Indumentis laxis. *Regitur* Opinionibus.
Afer	δ.	Niger, phlegmaticus, laxus. *Pilis* atris, contortuplicatis. *Cute* holosericea. *Naso* simo. *Labiis* tumidis. *Feminis* sinus pudoris. *Mammæ* lactantes prolixæ. *Vafer*, segnis, negligens. *Ungit* se pingui. *Regitur* Arbitrio.
Monstrosus	ε.	Solo (a) et arte (b c) variat.: a. *Alpini* parvi, agiles, timidi. *Patagonici* magni, segnes. b. *Monorchides* ut minus fertiles: Hottentotti. *Junceæ* puellæ, abdomine attenuato: Europææ. c. *Macrocephali* capiti conico: Chinenses. *Plagiocephali* capite antice compresso: Canadenses.

Turn a few pages further on in the same volume, and there appears, with a fine impartiality in the distribution of capitals and subdivisional headings:—

III. FERÆ.

Dentes primores superiores sex, acutiusculi. Canini solitarii.

. . . .

12. CANIS.		*Dentes primores* superiores VI.: laterales longiores distantes: intermedii lobati. Inferiores VI.: laterales lobati. *Laniarii* solitarii, incurvati. Molares VI. s. VII. (pluresve quam in reliquis).
familiaris	1.	C. cauda (sinistrorsum) recurvata. . . .
domesticus	α.	auriculis erectis, cauda subtus lanata.
sagax	β.	auriculis pendulis, digito spurio ad tibias posticas.
grajus	γ.	magnitudine lupi, trunco curvato, rostro attenuato, etc., etc.

Linnæus' definition of what he considers to be mere varieties of the species Man are, it will be observed, as completely free from any illusion to linguistic peculiarities as those brief and pregnant sentences in which he sketches the characters of the varieties of the species Dog. "Pilis nigris, naribus patulis" may be set against "auriculis erectis, cauda subtus lanata;"

while the remarks on the morals and manners of the human subject seem as if they were thrown in merely by way of make-weight.

Buffon, Blumenbach (the founder of ethnology as a special science), Rudolphi, Bory de St. Vincent, Desmoulins, Cuvier, Retzius, indeed I may say all the naturalists proper, have dealt with man from a no less completely zoological point of view; while, as might have been expected, those who have been least naturalists, and most linguists, have most neglected the zoological method, the neglect culminating in those who have been altogether devoid of acquaintance with anatomy.

Prichard's proposition that language is more persistent than physical characters is one which has never been proved, and indeed admits of no proof, seeing that the records of language do not extend so far as those of physical characters. But, until the superior tenacity of linguistic over physical peculiarities is shown, and until the abundant evidence which exists, that the language of a people may change without corresponding physical change in that people, is shown to be valueless, it is plain that the zoological court of appeal is the highest for the ethnologist, and that no evidence can be set against that derived from physical characters.

What, then, will a new survey of mankind from the Linnean point of view teach us?

The great antipodal block of land we call Australia has, speaking roughly, the form of a vast quadrangle, 2000 miles on the side, and extends from the hottest tropical, to the middle of the temperate, zone. Setting aside the foreign colonists introduced within the last century, it is inhabited by people no less remarkable for the uniformity, than for the singularity, of their physical characters and social state. For the most part of fair stature, erect and well built, except for an unusual slenderness of the lower limbs, the AUSTRALIANS have dark, usually chocolate-coloured skins; fine dark wavy hair; dark eyes, overhung by beetle brows; coarse, projecting jaws; broad and dilated, but not especially flattened, noses, and lips which, though prominent, are eminently flexible.

The skulls of these people are always long and narrow, with a smaller development of the frontal sinuses than usually corresponds with such largely developed brow ridges. An Australian skull of a round form, or one the transverse diameter of which

exceeds eight-tenths of its length, has never been seen. These people, in a word, are eminently "dolichocephalic," or long-headed; but, with this one limitation, their crania present considerable variations, some being comparatively high and arched, while others are more remarkably depressed than almost any other human skulls.

The female pelvis differs comparatively little from the European; but in the pelves of male Australians which I have examined, the antero-posterior and transverse diameters approach equality more nearly than is the case in Europeans.

No Australian tribe has ever been known to cultivate the ground, to use metals, pottery, or any kind of textile fabric. They rarely construct huts. Their means of navigation are limited to rafts or canoes, made of sheets of bark. Clothing, except skin cloaks for protection from cold, is a superfluity with which they dispense; and though they have some singular weapons, almost peculiar to themselves, they are wholly unacquainted with bows and arrows.

It is but a step, as it were, across Bass's Straits to Tasmania. Neither climate nor the characteristic forms of vegetable or animal life change largely on the south side of the Straits, but the early voyagers found Man singularly different from him on the north side. The skin of the Tasmanian was dark, though he lived between parallels of latitude corresponding with those of middle Europe in our own hemisphere; his jaws projected, his head was long and narrow; his civilisation was about on a footing with that of the Australian, if not lower, for I cannot discover that the Tasmanian understood the use of the throwing-stick. But he differed from the Australian in his woolly, negro-like hair; whence the name of NEGRITO, which has been applied to him and his congeners.

Such Negritos—differing more or less from the Tasmanian but agreeing with him in dark skin and woolly hair—occupy New Caledonia, the New Hebrides, the Louisiade Archipelago; and stretching to the Papuan Islands, and for a doubtful extent beyond them to the north and west, form a sort of belt, or zone, of Negrito population, interposed between the Australians on the west and the inhabitants of the great majority of the Pacific islands on the east.

The cranial characters of the Negritos vary considerably more than those of their skin and hair, the most notable circumstance being the strong Australian aspect which distinguishes many

Negrito skulls, while others tend rather towards forms common in the Polynesian islands.

In civilisation, New Caledonia exhibits an advance upon Tasmania, and farther north, there is a still greater improvement. But the bows and arrows, the perched houses, the outrigger canoes, the habits of betel-chewing and of kawa-drinking, which abound more or less among the northern Negritos, are probably to be regarded not as the products of an indigenous civilisation, but merely as indications of the extent to which foreign influences have modified the primitive social state of these people.

From Tasmania or New Caledonia, to New Zealand or Tongataboo, is again but a brief voyage: but it brings about a still more notable change in the aspect of the indigenous population than that effected by the passage of Bass's Straits. Instead of being chocolate-coloured people, the Maories and Tongans are light brown; instead of woolly, they have straight, or wavy black hair. And if from New Zealand, we travel some 5000 miles east to Easter Island; and from Easter Island, for as great a distance north-west, to the Sandwich Islands; and thence 7000 miles, westward and southward, to Sumatra; and even across the Indian Ocean, into the interior of Madagascar, we shall everywhere meet with people whose hair is straight or wavy, and whose skins exhibit various shades of brown. These are the Polynesians, Micronesians, Indonesians, whom Latham has grouped together under the common title of AMPHINESIANS.

The cranial characters of these people, as of the Negritos, are less constant than those of their skin and hair. The Maori has a long skull; the Sandwich Islander a broad skull. Some, like these, have strong brow ridges; others like the Dayaks and many Polynesians, have hardly any nasal indentation.

It is only in the westernmost parts of their area that the Amphinesian nations know anything about bows and arrows as weapons, or are acquainted with the use of metals or with pottery. Everywhere they cultivate the ground, construct houses, and skilfully build and manage outrigger, or double, canoes; while, almost everywhere, they use some kind of fabric for clothing.

Between Easter Island, or the Sandwich Islands, and any part of the American coast is a much wider interval than that between Tasmania and New Zealand, but the ethnological interval between the American and the Polynesian is less than that between either of the previously named stocks.

The typical AMERICAN has straight black hair and dark eyes, his skin exhibiting various shades of reddish, or yellowish brown, sometimes inclining to olive. The face is broad and scantily bearded; the skull wide and high. Such people extend from Patagonia to Mexico, and far farther north along the west coast. In the main a race of hunters, they had nevertheless, at the time of the discovery of the Americas, attained a remarkable degree of civilisation in some localities. They had domesticated ruminants, and not only practised agriculture, but had learned the value of irrigation. They manufactured textile fabrics, were masters of the potter's art, and knew how to erect massive buildings of stone. They understood the working of the precious, though not of the useful, metals; and had even attained to a rude kind of hieroglyphic, or picture, writing.

The Americans not only employ the bow and arrow, but, like some Amphinesians, the blow-pipe, as offensive weapons; but I am not aware that the outrigger canoe has ever been observed among them.

I have reason to suspect that some of the Fuegian tribes differ cranially from the typical Americans; and the Northern and Eastern American tribes have longer skulls than their Southern compatriots. But the ESQUIMAUX, who roam on the desolate and ice-bound coast of Arctic America, certainly present us with a new stock. The Esquimaux (among whom the Greenlanders are included), in fact, though they share the straight black hair of the proper Americans, are generally a duller complexioned, shorter, and a more squat people, and they have still more prominent cheek-bones. But the circumstances which most completely separates them from the typical Americans, is the form of their skulls, which instead of being broad, high, and truncated behind, are eminently long, usually low, and prolonged backwards.

These Hyperborean people clothe themselves in skins, know nothing of pottery, and hardly anything of metals. Dependent for existence upon the produce of the chase, the seal and the whale are to them what the cocoa-nut tree and the plantain are to the savages of more genial climates. Not only are those animals meat and raiment, but they are canoes, sledges, weapons, tools, windows, and fire; while they support the dog, who is the indispensable ally and beast of burden of the Esquimaux.

It is admitted that the Tchuktchi, on the eastern side of Behring's Straits, are, in all essential respects, Esquimaux;

and I do not know that there is any satisfactory evidence to show that the Tunguses and Samoiedes do not essentially share the same physical characters of the same people. Southward, there are indications of Esquimaux characters among the Japanese, and it is possible that their influence may be traced yet further.

However this may be, Eastern Asia, from Mantchouria to Siam, Thibet, and Northern Hindostan, is continuously inhabited by men, usually of short stature, with skins varying in colour from yellow to olive; with broad cheek-bones and faces that, owing to the insignificance of the nose, are exceedingly flat; and with obliquely-set small black eyes and straight black hair, which sometimes attains a very great length upon the scalp, but is always scanty upon the face, and body. The skull never much elongated, and is generally remarkably broad and rounded, with hardly any nasal depression, and but slight, if any, projection of the jaws.

Many of these people, for whom the old name of MONGOLIANS may be retained, are nomades; others, as the Chinese, have attained a remarkable and apparently indigenous civilisation, only surpassed by that of Europe.

At the north-western extremity of Europe the Lapps repeat the characters of the Eastern Asiatics. Between these extreme points, the Mongolian stock is not continuous, but is represented by a chain of more or less isolated tribes, who pass under the name of Calmucks and Tartars, and form Mongolian islands, as it were, in the midst of an ocean of other people.

The waves of this ocean are the nations for whom, in order to avoid the endless confusion produced by our present half-physical, half-philological classification, I shall use a new name —XANTHOCHROI—indicating that they are "yellow" haired and "pale" in complexion. The Chinese historians of the Han dynasty, writing in the third century before our era, describe, with much minuteness, certain numerous and powerful barbarians with "yellow hair, green eyes, and prominent noses," who, the black-haired, skew-eyed, and flat-nosed annalists remark in passing, are "just like the apes, from whom they are descended." These people held, in force, the upper waters of the Yenisei, and thence under various names stretched so thward to Thibet and Kashgar. Fair-haired and blue-eyed northern enemies were no less known to the ancient Hindoos, to the Persians, and to the Egyptians, on the south and west of

the great central Asiatic area; while the testimony of all European antiquity is to the effect that, before and since the period in question, there lay beyond the Danube, the Rhine, and the Seine, a vast and dangerous yellow or red haired, fair-skinned, blue-eyed population. Whether the disturbers of the marches of the Roman Empire were called Gauls or Germans, Goths, Alans, or Scythians, one thing seems certain, that until the invasion of the Huns, they were largely tall, fair, blue-eyed men.

If any one should think fit to assume that in the year 100 B.C., there was one continuous Xanthochroic population from the Rhine to the Yenisei, and from the Ural mountains to the Hindoo Koosh, I know not that any evidence exists by which that position could be upset, while the existing state of things is rather in its favour than otherwise. For the Scandinavians, wholly, the Germans, to a great extent, the Slavonian and the Finnish tribes, some of the inhabitants of Greece, many Turks, some Kirghis, and some Mantchous, the Ossetes in the Caucasus, the Siahposh, the Rohillas, are at the present day fair, yellow or red haired, and blue-eyed; and the interpolation of tribes of Mongolian hair and complexion, as far west as the Caspian Steppes and the Crimea, might justly be accounted for by those subsequent westward irruptions of the Mongolian stock, of which history furnishes abundant testimony.

The furthermost limit of the Xanthochroi north-westward is Iceland and the British Isles; south-westward, they are traceable at intervals through Syria and the Berber country, ending in the Canary Islands.

The cranial characters of the Xanthochroi are not, at present, strictly definable. The Scandinavians are certainly long-headed; but many Germans, the Swiss so far as they are Germanised, the Slavonians, the Fins, and the Turks, are short-headed. What were the cranial characters of the ancient "U-suns" and "Tinglings" of the valley of the Yenisei is unknown.

West of the area occupied by the chief mass of the Xanthochroi, and north of the Sahara, is a broad belt of land, shaped like a ≻. Between the forks of the Y lies the Mediterranean; the stem of it is Arabia. The stem is bathed by the Indian Ocean, the western ends of the forks by the Atlantic. The majority of the people inhabiting the area thus roughly sketched have, like the Xanthochroi, prominent noses, pale skins and wavy hair, with abundant beards; but, unlike them, the hair is black

or dark, and the eyes usually so. They may thence be called the MELANOCHROI. Such people are found in the British Islands, in Western and Southern Gaul, in Spain, in Italy south of the Po, in parts of Greece, in Syria and Arabia, stretching as far northward and eastward as the Caucasus and Persia. They are the chief inhabitants of Africa north of the Sahara, and, like the Xanthochroi, they end in the Canary Islands. They are known as Kelts, Iberians, Etruscans, Romans, Pelasgians, Berbers, Semites. The majority of them are long-headed, and of smaller stature than the Xanthochroi.

It is needless to remark upon the civilisation of these two great stocks. With them has originated everything that is highest in science, in art, in law, in politics, and in mechanical inventions. In their hands, at the present moment, lies the order of the social world, and to them its progress is committed.

South of the Atlas, and of the Great Desert, Middle Africa exhibits a new type of humanity in the NEGRO, with his dark skin, woolly hair, projecting jaws, and thick lips. As a rule, the skull of the Nergo is remarkably long; it rarely approaches the broad type, and never exhibits the roundness of the Mongolian. A cultivator of the ground, and dwelling in villages; a maker of pottery, and a worker in the useful as well as the ornamental metals; employing the bow and arrow as well as the spear, the typical negro stands high in point of civilisation above the Australian.

Resembling the Negroes in cranial characters, the BUSHMEN of South Africa differ from them in their yellowish brown skins, their tufted hair, their remarkably small stature, and their tendency to fatty and other integumentary outgrowths; nor is the wonderful click with which their speech is interspersed to be overlooked in enumerating the physical characteristics of this strange people.

The so-called "Drawidian" populations of Southern Hindostan lead us back, physically as well as geographically, towards the Australians; while the diminutive MINCOPIES of the Andaman Islands lie midway between the Negro and Negrito races, and, as Mr. Busk has pointed out, occasionally present the rare combination of Brachycephaly, or short-headedness, with woolly hair.

In the preceding progress along the outskirts of the habitable world, eleven readily distinguishable stocks, or persistent modi-

fications, of mankind, have been recognised. I have purposely omitted such people as the Abyssinians and the Hindoos, whom there is every reason to believe result from the intermixture of distinct stocks. Perhaps I ought, for like reasons, to have ignored the Mincopies. But I do not pretend that my enumeration is complete or in any sense perfect. It is enough for my purpose if it be admitted (and I think it cannot be denied) that those which I have mentioned exist, are well marked, and occupy the greater part of the habitable globe.

In attempting to classify these persistent modifications after the manner of naturalists, the first circumstance that attracts one's attention, is the broad contrast between the people with straight and wavy hair, and those with crisp, woolly, or tufted hair. Bory de St. Vincent, noting the fundamental distinction, divided mankind accordingly into the two primary groups of *Leiotrichi* and *Ulotrichi*—terms which are open to criticism, but which I adopt in the accompanying table, because they have been used. It is better for science to accept a faulty name which has the merit of existence, than to burthen it with a faultless newly invented one:

	Leiotrichi.		Ulotrichi.	
	Dolichocephali.	Brachycephali.	Dolichocephali.	Brachycephali.
Leucous.	. . . . Xanthochroi			
Leucomelanous.	. . . . Melanochroi			
Xanthomelanous.	*Esquimaux.*	Mongolians.	*Bushmen.*	
	Amphinesians.			
	Americans.			
Melanous.	*Australians.*		Negroes.	*Mincopies* (?)
			Negritos.	

The names of the stocks known only since the fifteenth century are put into italics. If the "Skrälings" of the Norse discoverers of America were Esquimaux, Europeans became acquainted with the latter six or seven centuries earlier.

Under each of these divisions are two columns, one for the Brachycephali, or short heads, and one for the Dolichocephali,[1]

[1] Skulls, the transverse diameter of which is more than eight-tenths the long diameter, are short; those which have the transverse diameter less than eight-tenths the longitudinal, are long.

or long heads. Again, each column is subdivided transversely into four compartments, one for the "leucous," people with fair complexions and yellow or red hair; one for the "leucomelanous," with dark hair and pale skins; one for the "xanthomelanous," with black hair and yellow, brown, or olive skins; and one for the "melanous," with black hair and dark brown or blackish skins.

It is curious to observe that almost all the woolly-haired people are also long-headed; while among the straight-haired nations broad heads preponderate, and only two stocks, the Esquimaux and the Australians, are exclusively long-headed.

One of the acutest and most original of ethnologists, Desmoulins, originated the idea, which has subsequently been fully developed by Agassiz, that the distribution of the persistent modifications of man is governed by the same laws as that of other animals, and that both fall into the same great distributional provinces. Thus, Australia; America, south of Mexico; the Arctic regions; Europe, Syria, Arabia, and North Africa, taken together, are each regions eminently characterised by the nature of their animal and vegetable populations, and each, as we have seen, has its peculiar and characteristic form of man. But it may be doubted whether the parallel thus drawn will hold good strictly, and in all cases. The Tasmanian Fauna and Flora are essentially Australian, and the like is true, to a less extent, of many, if not of all, the Papuan islands; but the Negritos who inhabit these islands are strikingly different from the Australians. Again the differences between the Mongolians and the Xanthochroi are out of all proportion greater than those between the Faunæ and Floræ of Central and Eastern Asia. But whatever the difficulties in the way of the detailed application of this comparison of the distribution of men with that of animals, it is well worthy of being borne in mind, and carried as far as it will go.

Apart from all speculation, a very curious fact regarding the distribution of the persistent modifications of mankind becomes apparent on inspecting an Ethnological chart, projected in such a manner that the Pacific Ocean occupies its centre. Such a chart exhibits an Australian area occupied by dark smooth-haired people, separated by an incomplete inner zone of dark woolly-haired Negritos and Negroes, from an outer zone of comparatively pale and smooth-haired men, occupying the Americas, and nearly all Asia, and North Africa.

Such is a brief sketch of the characters and distribution of the persistent modifications, or stocks, of mankind at the present day. If we seek for direct evidence of how long this state of things has lasted, we shall find little enough, and that little far from satisfactory. Of the eleven different stocks enumerated, seven have been known to us for less than 400 years; and of these seven not one possessed a fragment of written history at the time it came into contact with European civilisation. The other four—the Negroes, Mongolians, Xanthochroi, and Melanochroi—have always existed in some of the localities in which they are now found, nor do the negroes ever seem to have voluntarily travelled beyond the limits of their present area. But ancient history is in a great measure the record of the mutual encroachments of the other three stocks.

On the whole, however, it is wonderful how little change has been effected by these mutual invasions and intermixtures. As at the present time, so at the dawn of history, the Melanochroi fringed the Atlantic and the Mediterranean; the Xanthochroi occupied most of Central and Eastern Europe, and much of Western and Central Asia; while Mongolians held the extreme east of the Old World. So far as history teaches us, the populations of Europe, Asia, and Africa were, twenty centuries ago, just what they are now, in their broad features and general distribution.

The evidence yielded by archæology is not very definite, but, so far as it goes, it is to much the same effect. The mound builders of Central America seem to have had the characteristic short and broad head of the modern inhabitants of that continent. The tumuli and tombs of Ancient Scandinavia, of pre-Roman Britain, of Gaul, of Switzerland, reveal two types of skull—a broad and a long—of which, in Scandinavia, the broad seems to have belonged to the older stock, while the reverse was probably the case in Britain, and certainly in Switzerland. It has been assumed that the broad-skulled people of ancient Scandinavia were Lapps; but there is no proof of the fact, and they may have been, like the broad-skulled Swiss and Germans, Xanthochroi. One of the greatest of ethnological difficulties is to know where the modern Swedes, Norsemen, and Saxons got their long heads, as all their neighbours, Fins, Lapps, Slavonians, and South Germans, are broad-headed. Again, who were the small-handed long-headed people of the "bronze epoch," and what has become of the infusion of their blood among the Xanthochroi?

At present Palæontology yields no safe data to the ethnologist. We know absolutely nothing of the ethnological characters of the men of Abbeville and Hoxne; but must be content with the demonstration, in itself of immense value, that Man existed in Western Europe when its physical condition was widely different from what it is now, and when animals existed, which, though they belong to what is, properly speaking, the present order of things, have long been extinct. Beyond the limits of a fraction of Europe, Palæontology tells us nothing of man or of his works.

To sum up our knowledge of the ethnological past of man: so far as the light is bright, it shows him substantially as he is now; and, when it grows dim, it permits us to see no sign that he was other than he is now.

It is a general belief that men of different stocks differ as much physiologically as they do morphologically; but it is very hard to prove, in any particular case, how much of a supposed national characteristic is due to inherent physiological peculiarities, and how much to the influence of circumstances. There is much evidence to show, however, that some stocks enjoy a partial or complete immunity from diseases which destroy, or decimate, others. Thus there seems good ground for the belief that Negroes are remarkably exempt from yellow fever; and that, among Europeans, the melanochroic people are less obnoxious to its ravages than the xanthochroic. But many writers, not content with physiological differences of this kind, undertake to prove the existence of others of far greater moment; and, indeed, to show that certain stocks of mankind exhibit, more or less distinctly, the physiological characters of true species. Unions between these stocks, and still more between the half-breeds arising from their mixture, are affirmed to be either infertile, or less fertile than those which take place between males and females of either stock under the same circumstances. Some go so far as to assert that no mixed breeds of mankind can maintain themselves without the assistance of one or other of the parent stocks, and that, consequently, they must inevitably be obliterated in the long run.

Here, again, it is exceedingly difficult to obtain trustworthy evidence and to free the effects of the pure physiological experiment from adventitious influences. The only trial which, by a strange chance, was kept clear of all such influences—the only instance in which two distinct stocks of mankind were crossed,

and their progeny intermarried without any admixture from without—is the famous case of the Pitcairn Islanders, who were the progeny of Bligh's English sailors by Tahitian women. The results of this experiment, as everybody knows, are dead against those who maintain the doctrine of human hybridity, seeing that the Pitcairn Islanders, even though they necessarily contracted consanguineous marriages, throve and multiplied exceedingly.

But those who are disposed to believe in this doctrine should study the evidence brought forward in its support by M. Broca, its latest and ablest advocate, and compare this evidence with that which the botanists, as represented by a Gaertner or by a Darwin, think it indispensable to obtain before they will admit the infertility of crosses between two allied kinds of plants. They will then, I think, be satisfied that the doctrine in question rests upon a very unsafe foundation; that the facts adduced in its support are capable of many other interpretations; and, indeed, that from the very nature of the case, demonstrative evidence one way or the other is almost unattainable. *A priori*, I should be disposed to expect a certain amount of infertility between some of the extreme modifications of mankind; and still more between the offsprings of their intermixture. *A posteriori*, I cannot discover any satisfactory proof that such infertility exists.

From the facts of ethnology I now turn to the theories and speculations of ethnologists, which have been devised to explain these facts, and to furnish satisfactory answers to the inquiry—what conditions have determined the existence of the persistent modifications of mankind, and have caused their distribution to be what it is?

These speculations may be grouped under three heads; firstly, the Monogenist hypotheses; secondly, those of the Polygenists; and thirdly, that which would result from a simple application of Darwinian principles to mankind.

According to the Monogenists, all mankind have sprung from a single pair, whose multitudinous progeny spread themselves over the world, such as it now is; and became modified into the forms we meet with in the various regions of the earth, by the effect of the climatal and other conditions to which they were subjected.

The advocates of this hypothesis are divisible into several schools. There are those who represent the most numerous,

respectable, and would-be orthodox of the public, and are what may be called "Adamites," pure and simple. They believe that Adam was made out of earth somewhere in Asia, about six thousand years ago; that Eve was modelled from one of his ribs; and that the progeny of these two having been reduced to the eight persons who were landed on the summit of Mount Ararat after an universal deluge, all the nations of the earth have proceeded from these last, have migrated to their present localities, and have become converted into Negroes, Australians, Mongolians, etc., within that time. Five-sixths of the public are taught this Adamitic Monogenism, as if it were an established truth, and believe it. I do not; and I am not acquainted with any man of science, or duly instructed person, who does.

A second school of monogenists, not worthy of much attention, attempts to hold a place midway between the Adamites and a third division, who take up a purely scientific position, and require to be dealt with accordingly. This third division, in fact, numbers in its ranks Linnæus, Buffon, Blumenbach, Cuvier, Prichard, and many distinguished living ethnologists.

These "Rational Monogenists," or, at any rate, the more modern among them, hold, firstly, that the present condition of the earth has existed for untold ages; secondly, that, at a remote period, beyond the ken of Archbishop Usher, man was created, somewhere between the Caucasus and the Hindoo Koosh; thirdly, that he might have migrated thence to all parts of the inhabited world, seeing that none of them are unattainable from some other inhabited part, by men provided with only such means of transport as savages are known to possess and must have invented; fourthly, that the operation of the existing diversities of climate and other conditions upon people so migrating, is sufficient to account for all the diversities of mankind.

Of the truth of the first of these propositions no competent judge now entertains any doubt. The second is more open to discussion; for, in these latter days many question the special creation of man: and even if his special creation be granted, there is not a shadow of a reason why he should have been created in Asia rather than anywhere else. Of all the odd myths that have arisen in the scientific world, the "Caucasian mystery," invented quite innocently by Blumenbach, is the oddest. A Georgian woman's skull was the handsomest in his collection. Hence it became his model exemplar of human skulls, from which

all others might be regarded as deviations; and out of this, by some strange intellectual hocus-pocus, grew up the notion that the Caucasian man is the prototypic "Adamic" man, and his country the primitive centre of our kind. Perhaps the most curious thing of all is, that the said Georgian skull, after all, is not a skull of average form, but distinctly belongs to the brachycephalic group.

With the third proposition I am quite disposed to agree, though it must be recollected that it is one thing to allow that a given migration is possible, and another to admit there is good reason to believe it has really taken place.

But I can find no sufficient ground for accepting the fourth proposition; and I doubt if it would ever have obtained its general currency except for the circumstance that fair Europeans are very readily tanned and embrowned by the sun. But I am not aware that there is a particle of proof that the cutaneous change thus effected can become hereditary, any more than that the enlarged livers, which plague our countrymen in India, can be transmitted;—while there is very strong evidence to the contrary. Not only, in fact, are there such cases as those of the English families in Barbadoes, who have remained for six generations unaltered in complexion, but which are open to the objection that they may have received infusions of fresh European blood; but there is the broad fact, that not a single indigenous Negro exists either in the great alluvial plains of tropical South America, or in the exposed islands of the Polynesian Archipelago, or among the populations of equatorial Borneo or Sumatra. No satisfactory explanation of these obvious difficulties has been offered by the advocates of the direct influence of conditions. And as for the more important modifications observed in the structure of the brain, and in the form of the skull, no one has ever pretended to show in what way they can be effected directly by climate.

It is here, in fact, that the strength of the Polygenists, or those who maintain that men primitively arose, not from one, but from many stocks, lies. Show us, they say to the Monogenists, a single case in which the characters of a human stock have been essentially modified without its being demonstrable, or, at least, highly probable, that there has been intermixture of blood with some foreign stock. Bring forward any instance in which a part of the world, formerly inhabited by one stock, is now the dwelling-place of another, and we will prove the

change to be the result of migration, or of intermixture, and not of modification of character by climatic influences. Finally, prove to us that the evidence in favour of the specific distinctness of many animals, admitted to be distinct species by all zoologists, is a whit better than that upon which we maintain the specific distinctness of men.

If presenting unanswerable objections to your adversary were the same thing as proving your own case, the Polygenists would be in a fair way towards victory; but, unfortunately, as I have already observed, they have as yet completely failed to adduce satisfactory positive proof of the specific diversity of mankind. Like the Monogenists, the Polygenists are of several sects; some imagine that their assumed species of mankind were created where we find them—the African in Africa, and the Australian in Australia, along with the other animals of their distributional province; others conceive that each species of man has resulted from the modification of some antecedent species of ape—the American from the broad-nosed Simians of the New World, the African from the Troglodytic stock, the Mongolian from the Orangs.

The first hypothesis is hardly likely to win much favour. The whole tendency of modern science is to thrust the origination of things further and further into the background; and the chief philosophical objection to Adam being, not his oneness, but the hypothesis of his special creation; the multiplication of that objection tenfold is, whatever it may look, an increase, instead of a diminution, of the difficulties of the case. And, as to the second alternative, it may safely be affirmed that, even if the differences between men are specific, they are so small, that the assumption of more than one primitive stock for all is altogether superfluous. Surely no one can now be found to assert that any two stocks of mankind differ as much as a chimpanzee and an orang do; still less that they are as unlike as either of these is to any New World Simian!

Lastly, the granting of the Polygenist premises does not, in the slightest degree, necessitate the Polygenist conclusion. Admit that Negroes and Australians, Negritos and Mongols are distinct species, or distinct genera, if you will, and you may yet, with perfect consistency, be the strictest of Monogenists, and even believe in Adam and Eve as the primæval parents of all mankind.

It is to Mr. Darwin we owe this discovery: it is he who, coming

forward in the guise of an eclectic philosopher, presents his doctrine as the key to ethnology, and as reconciling and combining all that is good in the Monogenistic and Polygenistic schools.

It is true that Mr. Darwin has not, in so many words, applied his views to ethnology; but even he who "runs and reads" the "Origin of Species" can hardly fail to do so; and, furthermore, Mr. Wallace and M. Pouchet have recently treated of ethnological questions from this point of view. Let me, in conclusion, add my own contribution to the same store.

I assume Man to have arisen in the manner which I have discussed elsewhere, and probably, though by no means necessarily, in one locality. Whether he arose singly, or a number of examples appeared contemporaneously, is also an open question for the believer in the production of species by the gradual modification of pre-existing ones. At what epoch of the world's history this took place, again, we have no evidence whatever. It may have been in the older tertiary, or earlier, but what is most important to remember, is, that the discoveries of late years have proved that man inhabited Western Europe, at any rate, before the occurrence of those great physical changes which have given Europe its present aspect. And as the same evidence shows that man was the contemporary of animals which are now extinct, it is not too much to assume that his existence dates back at least as far as that of our present Fauna and Flora, or before the epoch of the drift.

But, if this be true, it is somewhat startling to reflect upon the prodigious changes which have taken place in the physical geography of this planet since man has been an occupant of it. During that period the greater part of the British islands, of Central Europe, of Northern Asia, have been submerged beneath the sea and raised up again. So has the great desert of Sahara, which occupies the major part of Northern Africa. The Caspian and the Aral seas have been one, and their united waters have probably communicated with both the Arctic and the Mediterranean oceans. The greater part of North America has been under water, and has emerged. It is highly probable that a large part of the Malayan Archipelago has sunk, and that its primitive continuity with Asia has been destroyed. Over the great Polynesian area subsidence has taken place to the extent of many thousands of feet—subsidence of so vast a character, in fact, that if a continent like Asia had once occupied the area

of the Pacific, the peaks of its mountains would now show not more numerous than the islands of the Polynesian Archipelago.

What lands may have been thickly populated for untold ages, and subsequently have disappeared and left no sign above the waters, it is of course impossible for us to say; but unless we are to make the wholly unjustifiable assumption that no dry land rose elsewhere when our present dry land sank, there must be half-a-dozen Atlantises beneath the waves of the various oceans of the world. But if the regions which have undergone these slow and gradual, but immense alterations, were wholly or in part inhabited before the changes I have indicated began—and it is more probable that they were than that they were not—what a wonderfully efficient "Emigration Board" must have been at work all over the world long before canoes, or even rafts, were invented; and before men were impelled to wander by any desire nobler or stronger than hunger. And as these rude and primitive families were thrust, in the course of long series of generations, from land to land, impelled by encroachments of sea or of marsh, or by severity of summer heat or winter cold, to change their positions, what opportunities must have been offered for the play of natural selection, in preserving one family variation and destroying another!

Suppose, for example, that some families of a horde which had reached a land charged with the seeds of yellow fever, varied in the direction of woolliness of hair and darkness of skin. Then, if it be true that these physical characters are accompanied by comparative or absolute exemptions from that scourge, the inevitable tendency would be to the preservation and multiplication of the darker and woollier families, and the elimination of the whiter and smoother haired. In fact, by the operation of causes precisely similar to those which, in the famous instance cited by Mr. Darwin, have given rise to a race of black pigs in the forests of Louisiana, a negro stock would eventually people the region.

Again, how often, by such physical changes, must a stock have been isolated from all others for innumerable generations, and have found ample time for the hereditary hardening of its special peculiarities into the enduring characters of a persistent modification.

Nor, if it be true that the physiological differences of species may be produced by variation and natural selection, as Mr. Darwin supposes, would it be at all astonishing if, in some of

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these separated stocks, the process of differentiation should have gone so far as to give rise to the phenomena of hybridity. In the face of the overwhelming evidence in favour of the unity of the origin of mankind afforded by anatomical considerations, satisfactory proof of the existence of any degree of sterility in the unions of members of two of the "persistent modifications" of mankind, might well be appealed to by Mr. Darwin as crucial evidence of the truth of his views regarding the origin of species in general.

CRITICISMS ON "THE ORIGIN OF SPECIES"

In the course of the present year (1864) several foreign commentaries upon Mr. Darwin's great work have made their appearance. Those who have perused that remarkable chapter of the "Antiquity of Man," in which Sir Charles Lyell draws a parallel between the development of species and that of languages, will be glad to hear that one of the most eminent philologers of Germany, Professor Schleicher, has, independently, published a most instructive and philosophical pamphlet (an excellent notice of which is to be found in the "Reader," for February 27th of this year) supporting similar views with all the weight of his special knowledge and established authority as a linguist. Professor Haeckel, to whom Schleicher addresses himself, previously took occasion, in his splendid monograph on the *Radiolaria*,[1] to express his high appreciation of, and general concordance with, Mr. Darwin's views.

But the most elaborate criticisms of the "Origin of Species" which have appeared are two works of very widely different merit, the one by Professor Kölliker, the well-known anatomist and histologist of Würzburg, the other by M. Flourens, Perpetual Secretary of the French Academy of Sciences.

Professor Kölliker's critical essay "Upon the Darwinian Theory" is, like all that proceeds from the pen of that thoughtful and accomplished writer, worthy of the most careful consideration. It comprises a brief but clear sketch of Darwin's views, followed by an enumeration of the leading difficulties in the way of their acceptance; difficulties which would appear to be insurmountable to Professor Kölliker, inasmuch as he proposes to replace Mr. Darwin's Theory by one which he terms the "Theory of Heterogeneous Generation." We shall proceed to consider first the destructive, and secondly, the constructive portion of the essay.

We regret to find ourselves compelled to dissent very widely from many of Professor Kölliker's remarks; and from none

[1] "Die Radiolarien: eine Monographie," p. 231.

more thoroughly than from those in which he seeks to define what we may term the philosophical position of Darwinism.

"Darwin," says Professor Kölliker, "is, in the fullest sense of the word a Teleologist. He says quite distinctly (First Edition, pp. 199, 200) that every particular in the structure of an animal has been created for its benefit, and he regards the whole series of animal forms only from this point of view."

And again:

"7. The teleological general conception adopted by Darwin is a mistaken one.

"Varieties arise irrespectively of the notion of purpose, or of utility, according to general laws of nature, and may be either useful, or hurtful, or indifferent.

"The assumption that an organism exists only on account of some definite end in view, and represents something more than the incorporation of a general idea, or law, implies a one-sided conception of the universe. Assuredly, every organ has, and every organism fulfils, its end, but its purpose is not the condition of its existence. Every organism is also sufficiently perfect for the purpose it serves, and in that, at least, it is useless to seek for a cause of its improvement."

It is singular how differently one and the same book will impress different minds. That which struck the present writer most forcibly on his first perusal of the "Origin of Species" was the conviction that Teleology, as commonly understood, had received its deathblow at Mr. Darwin's hands. For the teleological argument runs thus: an organ or organism (A) is precisely fitted to perform a function or purpose (B); therefore it was specially constructed to perform that function. In Paley's famous illustration, the adaptation of all the parts of the watch to the function, or purpose, of showing the time is held to be evidence that the watch was specially contrived to that end; on the ground, that the only cause we know of, competent to produce such an effect as a watch which shall keep time, is a contriving intelligence adapting the means directly to that end.

Suppose, however, that any one had been able to show that the watch had not been made directly by any person, but that it was the result of the modification of another watch which kept time but poorly; and that this again had proceeded from a structure which could hardly be called a watch at all—seeing that it had no figures on the dial and the hands were rudimentary; and that going back and back in time we came at last to a revolving barrel as the earliest traceable rudiment of the whole fabric. And imagine that it had been possible to show that all these changes had resulted, first, from a tendency of the structure

to vary indefinitely; and secondly, from something in the surrounding world which helped all variations in the direction of an accurate time-keeper, and checked all those in other directions; then it is obvious that the force of Paley's argument would be gone. For it would be demonstrated that an apparatus thoroughly well adapted to a particular purpose might be the result of a method of trial and error worked by unintelligent agents, as well as of the direct application of the means appropriate to that end, by an intelligent agent.

Now it appears to us that what we have here, for illustration's sake, supposed to be done with the watch is exactly what the establishment of Darwin's Theory will do for the organic world. For the notion that every organism has been created as it is and launched straight at a purpose, Mr. Darwin substitutes the conception of something which may fairly be termed a method of trial and error. Organisms vary incessantly; of these variations the few meet with surrounding conditions which suit them and thrive; the many are unsuited and become extinguished.

According to Teleology each organism is like a rifle bullet fired straight at a mark; according to Darwin, organisms are like grapeshot of which one hits something and the rest fall wide.

For the teleologist an organism exists because it was made for the conditions in which it is found; for the Darwinian an organism exists because, out of many of its kind, it is the only one which has been able to persist in the conditions in which it is found.

Teleology implies that the organs of every organism are perfect and cannot be improved; the Darwinian theory simply affirms that they work well enough to enable the organism to hold its own against such competitors as it has met with, but admits the possibility of indefinite improvement. But an example may bring into clearer light the profound opposition between the ordinary Teleological and the Darwinian conception.

Cats catch mice, small birds and the like, very well. Teleology tells us that they do so because they were expressly constructed for so doing—that they are perfect mousing apparatuses, so perfect and so delicately adjusted that no one of their organs could be altered, without the change involving the alteration of all the rest. Darwinism affirms, on the contrary, that there was no express construction concerned in the matter; but that among the multitudinous variations of the Feline stock, many of which died out from want of power to resist opposing in-

fluences, some, the cats, were better fitted to catch mice than others, whence they throve and persisted in proportion to the advantage over their fellows thus offered to them.

Far from imagining that cats exist *in order* to catch mice well, Darwinism supposes that cats exist *because* they catch mice well—mousing being not the end, but the condition, of their existence, and if the cat-type has long persisted as we know it, the interpretation of the fact upon Darwinian principles would be, not that the cats have remained invariable, but that such varieties as have incessantly occurred have been, on the whole, less fitted to get on in the world than the existing stock.

If we apprehend the spirit of the "Origin of Species" rightly, then, nothing can be more entirely and absolutely opposed to Teleology, as it is commonly understood, than the Darwinian Theory. So far from being a "Teleologist in the fullest sense of the word," we should deny that he is a Teleologist in the ordinary sense at all; and we should say that, apart from his merits as a naturalist, he has rendered a most remarkable service to philosophical thought by enabling the student of nature to recognise, to their fullest extent, those adaptations to purpose which are so striking in the organic world, and which Teleology has done good service in keeping before our minds, without being false to the fundamental principles of a scientific conception of the universe. The apparently diverging teachings of the teleologist and of the morphologist are reconciled by the Darwinian hypothesis.

But leaving our own impressions of the "Origin of Species," and turning to those passages specially cited by Professor Kölliker, we cannot admit that they bear the interpretation he puts upon them. Darwin, if we read him rightly, does *not* affirm that every detail in the structure of an animal has been created for its benefit. His words are (p. 199):—

"The foregoing remarks lead me to say a few words on the protest lately made by some naturalists against the utilitarian doctrine that every detail of structure has been produced for the good of its possessor. They believe that very many structures have been created for beauty in the eyes of man, or for mere variety. This doctrine, if true, would be absolutely fatal to my theory—yet I fully admit that many structures are of no direct use to their possessor."

And after sundry illustrations and qualifications, he concludes (p. 200):—

"Hence every detail of structure in every living creature (making some little allowance for the direct action of physical conditions) may be viewed

either as having been of special use to some ancestral form, or as being now of special use to the descendants of this form—either directly, or indirectly, through the complex laws of growth."

But it is one thing to say, Darwinically, that every detail observed in an animal's structure is of use to it, or has been of use to its ancestors; and quite another to affirm, teleologically, that every detail of an animal's structure has been created for its benefit. On the former hypothesis, for example, the teeth of the fœtal *Balæna* have a meaning; on the latter, none. So far as we are aware, there is not a phrase in the "Origin of Species" inconsistent with Professor Kölliker's position, that "varieties arise irrespectively of the notion of purpose, or of utility, according to general laws of nature, and may be either useful, or hurtful, or indifferent."

On the contrary, Mr. Darwin writes (Summary of Chap. V.):—

"Our ignorance of the laws of variation is profound. Not in one case out of a hundred can we pretend to assign any reason why this or that part varies more or less from the same part in the parents. . . . The external conditions of life, as climate and food, etc., seem to have induced some slight modifications. Habit in producing constitutional differences, and use, in strengthening, and disuse, in weakening and diminishing organs, seem to have been more potent in their effects."

And finally, as if to prevent all possible misconception, Mr. Darwin concludes his Chapter on Variation with these pregnant words:—

"Whatever the cause may be of each slight difference in the offspring from their parents—and a cause for each must exist—it is the steady accumulation, through natural selection of such differences, when beneficial to the individual, that gives rise to all the more important modifications of structure, by which the innumerable beings on the face of the earth are enabled to struggle with each other, and the best adapted, to survive."

We have dwelt at length upon this subject, because of its great general importance, and because we believe that Professor Kölliker's criticisms on this head are based upon a misapprehension of Mr. Darwin's views—substantially they appear to us to coincide with his own. The other objections which Professor Kölliker enumerates and discusses are the following: [1]—

"1. No transitional forms between existing species are known; and known varieties, whether selected or spontaneous, never go so far as to establish new species."

To this Professor Kölliker appears to attach some weight.

[1] Space will not allow us to give Professor Kölliker's arguments in detail; our readers will find a full and accurate version of them in the "Reader" for August 13th and 20th, 1864.

He makes the suggestion that the short-faced tumbler pigeon may be a pathological product.

"2. No transitional forms of animals are met with among the organic remains of earlier epochs."

Upon this, Professor Kölliker remarks that the absence of transitional forms in the fossil world, though not necessarily fatal to Darwin's views, weakens his case.

"3. The struggle for existence does not take place."

To this objection, urged by Pelzeln, Kölliker, very justly, attaches no weight.

"4. A tendency of organisms to give rise to useful varieties, and a natural selection, do not exist.

"The varieties which are found arise in consequence of manifold external influences, and it is not obvious why they all, or partially, should be particularly useful. Each animal suffices for its own ends, is perfect of its kind, and needs no further development. Should, however, a variety be useful and even maintain itself, there is no obvious reason why it should change any further. The whole conception of the imperfection of organisms and the necessity of their becoming perfected is plainly the weakest side of Darwin's Theory, and a *pis aller* (Nothbehelf) because Darwin could think of no other principle by which to explain the metamorphoses which, as I also believe, have occurred."

Here again we must venture to dissent completely from Professor Kölliker's conception of Mr. Darwin's hypothesis. It appears to us to be one of the many peculiar merits of that hypothesis that it involves no belief in a necessary and continual progress of organisms.

Again, Mr. Darwin, if we read him aright, assumes no special tendency of organisms to give rise to useful varieties, and knows nothing of needs of development, or necessity of perfection. What he says is, in substance: All organisms vary. It is in the highest degree improbable that any given variety should have exactly the same relations to surrounding conditions as the parent stock. In that case it is either better fitted (when the variation may be called useful) or worse fitted, to cope with them. If better, it will tend to supplant the parent stock; if worse, it will tend to be extinguished by the parent stock.

If (as is hardly conceivable) the new variety is so perfectly adapted to the conditions that no improvement upon it is possible,—it will persist, because though it does not cease to vary, the varieties will be inferior to itself.

If, as is more probable, the new variety is by no means

perfectly adapted to its conditions, but only fairly well adapted to them, it will persist, so long as none of the varieties which it throws off are better adapted than itself.

On the other hand, as soon as it varies in a useful way, *i.e.* when the variation is such as to adapt it more perfectly to its conditions, the fresh variety will tend to supplant the former.

So far from a gradual progress towards perfection forming any necessary part of the Darwinian creed, it appears to us that it is perfectly consistent with indefinite persistence in one state, or with a gradual retrogression. Suppose, for example, a return of the glacial epoch and a spread of polar climatal conditions over the whole globe. The operation of natural selection under these circumstances would tend, on the whole, to the weeding out of the higher organisms and the cherishing of the lower forms of life. Cryptogamic vegetation would have the advantage over Phanerogamic; Hydrozoa over Corals; Crustacea over Insecta, and Amphipoda and Isopoda over the higher Crustacea; Cetaceans and Seals over the Primates; the civilisation of the Esquimaux over that of the European.

"5. Pelzeln has also objected that if the later organisms have proceeded from the earlier, the whole developmental series, from the simplest to the highest, could not now exist; in such a case the simpler organisms must have disappeared."

To this Professor Kölliker replies, with perfect justice, that the conclusion drawn by Pelzeln does not really follow from Darwin's premises, and that, if we take the facts of Palæontology as they stand, they rather support than oppose Darwin's theory.

"6. Great weight must be attached to the objection brought forward by Huxley, otherwise a warm supporter of Darwin's hypothesis, that we know of no varieties which are sterile with one another, as is the rule among sharply distinguished animal forms.

"If Darwin is right, it must be demonstrated that forms may be produced by selection, which, like the present sharply distinguished animal forms, are infertile, when coupled with one another, and this has not been done."

The weight of this objection is obvious; but our ignorance of the conditions of fertility and sterility; the want of carefully conducted experiments extending over long series of years, and the strange anomalies presented by the results of the cross-fertilisation of many plants, should all, as Mr. Darwin has urged, be taken into account in considering it.

The seventh objection is that we have already discussed.

The eighth and last stands as follows:—

"8. The developmental theory of Darwin is not needed to enable us to understand the regular harmonious progress of the complete series of organic forms from the simpler to the more perfect.

"The existence of general laws of nature explains this harmony, even if we assume that all beings have arisen separately and independent of one another. Darwin forgets that inorganic nature, in which there can be no thought of genetic connection of forms, exhibits the same regular plan, the same harmony, as the organic world; and that, to cite only one example, there is as much a natural system of minerals as of plants and animals."

We do not feel quite sure that we seize Professor Kölliker's meaning here, but he appears to suggest that the observation of the general order and harmony which pervade inorganic nature, would lead us to anticipate a similar order and harmony in the organic world. And this is no doubt true, but it by no means follows that the particular order and harmony observed among them should be that which we see. Surely the stripes of dun horses, and the teeth of the fœtal *Balæna*, are not explained by the "existence of general laws of nature." Mr. Darwin endeavours to explain the exact order of organic nature which exists; not the mere fact that there is some order.

And with regard to the existence of a natural system of minerals; the obvious reply is that there may be a natural classification of any objects—of stones on a sea-beach, or of works of art; a natural classification being simply an assemblage of objects in groups, so as to express their most important and fundamental resemblances and differences. No doubt Mr. Darwin believes that those resemblances and differences upon which our natural systems or classifications of animals and plants are based, are resemblances and differences which have been produced genetically, but we can discover no reason for supposing that he denies the existence of natural classifications of other kinds.

And, after all, is it quite so certain that a genetic relation may not underlie the classification of minerals? The inorganic world has not always been what we see it. It has certainly had its metamorphoses, and, very probably, a long "Entwickelungsgeschichte" out of a nebular blastema. Who knows how far that amount of likeness among sets of minerals, in virtue of which they are now grouped into families and orders, may not be the expression of the common conditions to which that particular patch of nebulous fog, which may have been

constituted by their atoms, and of which they may be, in the strictest sense, the descendants, was subjected?

It will be obvious from what has preceded, that we do not agree with Professor Kölliker in thinking the objections which he brings forward so weighty as to be fatal to Darwin's view. But even if the case were otherwise, we should be unable to accept the "Theory of Heterogeneous Generation" which is offered as a substitute. That theory is thus stated:—

"The fundamental conception of this hypothesis is, that, under the influence of a general law of development, the germs of organisms produce others different from themselves. This might happen (1) by the fecundated ova passing, in the course of their development, under particular circumstances, into higher forms; (2) by the primitive and later organisms producing other organisms without fecundation, out of germs or eggs (Parthenogenesis)."

In favour of this hypothesis, Professor Kölliker adduces the well-known facts of Agamogenesis, or "alternate generation"; the extreme dissimilarity of the males and females of many animals; and of the males, females, and neuters of those insects which live in colonies; and he defines its relations to the Darwinian theory as follows:—

"It is obvious that my hypothesis is apparently very similar to Darwin's, inasmuch as I also consider that the various forms of animals have proceeded directly from one another. My hypothesis of the creation of organisms by heterogeneous generation, however, is distinguished very essentially from Darwin's by the entire absence of the principle of useful variations and their natural selection: and my fundamental conception is this, that a great plan of development lies at the foundation of the origin of the whole organic world, impelling the simpler forms to more and more complex developments. How this law operates, what influences determine the development of the eggs and germs, and impel them to assume constantly new forms, I naturally cannot pretend to say; but I can at least adduce the great analogy of the alternation of generations. If a *Bipinnaria*, a *Brachialaria*, a *Pluteus*, is competent to produce the Echinoderm, which is so widely different from it; if a hydroid polype can produce the higher Medusa; if the vermiform Trematode 'nurse' can develop within itself the very unlike *Cercaria*, it will not appear impossible that the egg, or ciliated embryo, of a sponge, for once, under special conditions, might become a hydroid polype, or the embryo of a Medusa, an Echinoderm."

It is obvious, from these extracts, that Professor Kölliker's hypothesis is based upon the supposed existence of a close analogy between the phænomena of Agamogenesis and the production of new species from pre-existing ones. But is the analogy a real one? We think that it is not, and, by the hypothesis, cannot be.

For what are the phænomena of Agamogenesis, stated generally? An impregnated egg develops into an asexual form, A; this gives rise, asexually, to a second form or forms, B, more or less different from A. B may multiply asexually again; in the simpler cases, however, it does not, but, acquiring sexual characters, produces impregnated eggs from whence A, once more, arises.

No case of Agamogenesis is known in which *when A differs widely from B,* it is itself capable of sexual propagation. No case whatever is known in which the progeny of B, by sexual generation, is other than a reproduction of A.

But if this be a true statement of the nature of the process of Agamogenesis, how can it enable us to comprehend the production of new species from already existing ones? Let us suppose Hyænas to have preceded Dogs, and to have produced the latter in this way. Then the Hyæna will represent A, and the Dog B. The first difficulty that presents itself is that the Hyæna must be asexual or the process will be wholly without analogy in the world of Agamogenesis. But passing over this difficulty, and supposing a male and female Dog to be produced at the same time from the Hyæna stock, the progeny of the pair, if the analogy of the simpler kinds of Agamogenesis [1] is to be followed, should be a litter, not of puppies, but of young Hyænas. For the Agamogenetic series is always, as we have seen, A : B : A : B, etc.; whereas, for the production of a new species, the series must be A : B : B : B, etc. The production of new species, or genera, is the extreme permanent divergence from the primitive stock. All known Agamogenetic processes on the other hand end in a complete return to the primitive stock. How then is the production of new species to be rendered intelligible by the analogy of Agamogenesis?

The other alternative put by Professor Kölliker—the passage of fecundated ova in the course of their development into higher forms—would, if it occurred, be merely an extreme case of

[1] If, on the contrary, we follow the analogy of the more complex forms of Agamogenesis, such as that exhibited by some *Trematoda* and by the *Aphides*, the Hyæna must produce, asexually, a brood of asexual Dogs, from which other sexless Dogs must proceed. At the end of a certain number of terms of the series, the Dogs would acquire sexes and generate young; but these young would be, not Dogs, but Hyænas. In fact, we have *demonstrated* in Agamogenetic phænomena, that inevitable recurrence to the original type, which is *asserted* to be true of variations in general, by Mr. Darwin's opponents; and which, if the assertion could be changed into a demonstration, would, in fact, be fatal to his hypothesis.

variation in the Darwinian sense, greater in degree than, but perfectly similar in kind to, that which occurred when the well-known Ancon Ram was developed from an ordinary Ewe's ovum. Indeed we have always thought that Mr. Darwin has unnecessarily hampered himself by adhering so strictly to his favourite "Natura non facit saltum." We greatly suspect that she does make considerable jumps in the way of variation now and then, and that these saltations give rise to some of the gaps which appear to exist in the series of known forms.

Strongly and freely as we have ventured to disagree with Professor Kölliker, we have always done so with regret, and we trust without violating that respect which is due, not only to his scientific eminence and to the careful study which he has devoted to the subject, but to the perfect fairness of his argumentation, and the generous appreciation of the worth of Mr. Darwin's labours which he always displays. It would be satisfactory to be able to say as much for M. Flourens.

But the Perpetual Secretary of the French Academy of Sciences deals with Mr. Darwin as the first Napoleon would have treated an "ideologue;" and while displaying a painful weakness of logic and shallowness of information, assumes a tone of authority, which always touches upon the ludicrous, and sometimes passes the limits of good breeding.

For example (p. 56):—

"M. Darwin continue: 'Aucune distinction absolue n'a été et ne peut être établie entre les espèces et les variétés.' Je vous ai déjà dit que vous vous trompiez; une distinction absolue sépare les variétés d'avec les espèces."

"*Je vous ai déjà dit;* moi, M. le Secrétaire perpétuel de l'Académie des Sciences: et vous

> "'Qui n'êtes rien,
> Pas même Académicien;'

what do you mean by asserting the contrary?" Being devoid of the blessings of an Academy in England, we are unaccustomed to see our ablest men treated in this fashion, even by a "Perpetual Secretary."

Or again, considering that if there is any one quality of Mr. Darwin's work to which friends and foes have alike borne witness, it is his candour and fairness in admitting and discussing

objections, what is to be thought of M. Flourens' assertion, that:—

"M. Darwin ne cite que les auteurs qui partagent ses opinions" (p. 40).

Once more (p. 65):—

"Enfin l'ouvrage de M. Darwin a paru. On ne peut qu'être frappé du talent de l'auteur. Mais que d'idées obscures, que d'idées fausses! Quel jargon métaphysique jeté mal à propos dans l'histoire naturelle, qui tombe dans le galimatias dès qu'elle sort des idées claires, des idées justes! Quel langage prétentieux et vide. Quelles personnifications puériles et surannées! O lucidité! O solidité de l'esprit Français, que devenez-vous?"

"Obscure ideas," "metaphysical jargon," "pretentious and empty language," "puerile and superannuated personifications." Mr. Darwin has many and hot opponents on this side of the Channel and in Germany, but we do not recollect to have found precisely these sins in the long catalogue of those hitherto laid to his charge. It is worth while, therefore, to examine into these discoveries effected solely by the aid of the "lucidity and solidity" of the mind of M. Flourens.

According to M. Flourens, Mr. Darwin's great error is that he has personified nature (p. 10), and further that he has

"imagined a natural selection: he imagines afterwards that this power of selecting (*pouvoir d'élire*) which he gives to nature is similar to the power of man. These two suppositions admitted, nothing stops him: he plays with nature as he likes, and makes her do all he pleases" (p. 6).

And this is the way M. Flourens extinguishes natural selection:

"Voyons donc encore une fois, ce qu'il peut y avoir de fondé dans ce qu'on nomme *élection naturelle*.

"*L'élection naturelle* n'est sous un autre nom que la nature. Pour un être organisé, la nature n'est que l'organisation, ni plus ni moins.

"Il faudra donc aussi personnifier *l'organisation*, et dire que *l'organisation* choisit *l'organisation*. *L'élection naturelle* est cette *forme substantielle* dont on jouait autrefois avec tant de facilité. Aristote disait que 'Si l'art de bâtir était dans le bois, cet art agirait comme la nature.' A la place de *l'art de bâtir* M. Darwin met *l'élection naturelle*, et c'est tout un: l'un n'est pas plus chimérique que l'autre" (p. 31).

And this is really all that M. Flourens can make of Natural Selection. We have given the original, in fear lest a translation should be regarded as a travesty; but with the original before the reader, we may try to analyse the passage. "For an organised being, nature is only organisation, neither more nor less."

Organised beings then have absolutely no relation to inorganic nature: a plant does not depend on soil or sunshine, climate,

depth in the ocean, height above it; the quantity of saline matters in water have no influence upon animal life; the substitution of carbonic acid for oxygen in our atmosphere would hurt nobody! That these are absurdities no one should know better than M. Flourens; but they are logical deductions from the assertion just quoted, and from the further statement that natural selection means only that "organisation chooses and selects organisation."

For if it be once admitted (what no sane man denies) that the chances of life of any given organism are increased by certain conditions (A) and diminished by their opposites (B), then it is mathematically certain that any change of conditions in the direction of (A) will exercise a selective influence in favour of that organism, tending to its increase and multiplication, while any change in the direction of (B) will exercise a selective influence against that organism, tending to its decrease and extinction.

Or, on the other hand, conditions remaining the same, let a given organism vary (and no one doubts that they do vary) in two directions, into one form (*a*) better fitted to cope with these conditions than the original stock, and a second (*b*) less well adapted to them. Then it is no less certain that the conditions in question must exercise a selective influence in favour of (*a*) and against (*b*), so that (*a*) will tend to predominance, and (*b*) to extirpation.

That M. Flourens should be unable to perceive the logical necessity of these simple arguments, which lie at the foundation of all Mr. Darwin's reasoning; that he should confound an irrefragable deduction from the observed relations of organisms to the conditions which lie around them, with a metaphysical "forme substantielle," or a chimerical personification of the powers of nature, would be incredible, were it not that other passages of his work leave no room for doubt upon the subject.

"On imagine une *élection naturelle* que, pour plus de ménagement, on me dit être *inconsciente*, sans s'apercevoir que le contresens littéral est précisément là: *élection inconsciente*" (p. 52).

"J'ai déjà dit ce qu'il faut penser de *l'élection naturelle*. Ou *l'élection naturelle* n'est rien, ou c'est la nature: mais la nature douée *d'élection*, mais la nature personnifiée: dernière erreur du dernier siècle: Le xixe ne fait plus de personnifications" (p. 53).

M. Flourens cannot imagine an unconscious selection—it is for him a contradiction in terms. Did M. Flourens ever visit one of the prettiest watering-places of "la belle France," the Baie d'Arcachon? If so, he will probably have passed through

the district of the Landes, and will have had an opportunity of observing the formation of "dunes" on a grand scale. What are these "dunes"? The winds and waves of the Bay of Biscay have not much consciousness, and yet they have with great care "selected," from among an infinity of masses of silex of all shapes and sizes, which have been submitted to their action, all the grains of sand below a certain size, and have heaped them by themselves over a great area. This sand has been "unconsciously selected" from amidst the gravel in which it first lay with as much precision as if man had "consciously selected" it by the aid of a sieve. Physical Geology is full of such selections—of the picking out of the soft from the hard, of the soluble from the insoluble, of the fusible from the infusible, by natural agencies to which we are certainly not in the habit of ascribing consciousness.

But that which wind and sea are to a sandy beach, the sum of influences, which we term the "conditions of existence," is to living organisms. The weak are sifted out from the strong. A frosty night "selects" the hardy plants in a plantation from among the tender ones as effectually as if it were the wind, and they, the sand and pebbles, of our illustration; or, on the other hand, as if the intelligence of a gardener had been operative in cutting the weaker organisms down. The thistle, which has spread over the Pampas, to the destruction of native plants, has been more effectually "selected" by the unconscious operation of natural conditions than if a thousand agriculturists had spent their time in sowing it.

It is one of Mr. Darwin's many great services to Biological science that he has demonstrated the significance of these facts. He has shown that—given variation and given change of conditions—the inevitable result is the exercise of such an influence upon organisms that one is helped and another is impeded; one tends to predominate, another to disappear; and thus the living world bears within itself, and is surrounded by, impulses towards incessant change.

But the truths just stated are as certain as any other physical laws quite independently of the truth or falsehood of the hypothesis which Mr. Darwin has based upon them; and that M. Flourens, missing the substance and grasping at a shadow, should be blind to the admirable exposition of them which Mr. Darwin has given, and see nothing there but a "dernière erreur du dernier siècle"—a personification of nature—leads us

indeed to cry with him: "O lucidité! O solidité de l'esprit Français, que devenez-vous?"

M. Flourens has, in fact, utterly failed to comprehend the first principles of the doctrine which he assails so rudely. His objections to details are of the old sort, so battered and hackneyed on this side of the Channel, that not even a "Quarterly" Reviewer could be induced to pick them up for the purpose of pelting Mr. Darwin over again. We have Cuvier and the mummies; M. Roulin and the domesticated animals of America; the difficulties presented by hybridism and by Palæontology; Darwinism a *rifacciamento* of De Maillet and Lamarck; Darwinism a system without a commencement, and its author bound to believe in M. Pouchet, etc., etc. How one knows it all by heart, and with what relief one reads at p. 65—

"Je laisse M. Darwin!"

But we cannot leave M. Flourens without calling our readers' attention to his wonderful tenth chapter, "De la préexistence des Germes et de l'Epigénèse," which opens thus:—

"Spontaneous generation is only a chimæra. This point established, two hypotheses remain: that of *pre-existence* and that of *epigenesis*. The one of these hypotheses has as little foundation as the other" (p. 163).

"The doctrine of *epigenesis* is derived from Harvey: following by ocular inspection the development of the new being in the Windsor does, he saw each part appear successively, and taking the moment of *appearance* for the moment of *formation* he imagined *epigenesis*" (p. 165).

On the contrary, says M. Flourens (p. 167)—

"The new being is formed at a stroke (*tout d'un coup*), as a whole, instantaneously; it is not formed part by part, and at different times. It is formed at once at the single *individual* moment at which the conjunction of the male and female elements takes place."

It will be observed that M. Flourens uses language which cannot be mistaken. For him, the labours of Von Baer, of Rathke, of Coste, and their contemporaries and successors in Germany, France, and England, are non-existent: and, as Darwin "*imagina*" natural selection, so Harvey "*imagina*" that doctrine which gives him an even greater claim to the veneration of posterity than his better known discovery of the circulation of the blood.

Language such as that we have quoted is, in fact, so preposterous, so utterly incompatible with anything but absolute ignorance of some of the best established facts, that we should

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have passed it over in silence had it not appeared to afford some clue to M. Flourens' unhesitating, *à priori*, repudiation of all forms of the doctrine of progressive modification of living beings. He whose mind remains uninfluenced by an acquaintance with the phænomena of development, must indeed lack one of the chief motives towards the endeavour to trace a genetic relation between the different existing forms of life. Those who are ignorant of Geology, find no difficulty in believing that the world was made as it is; and the shepherd, untutored in history, sees no reason to regard the green mounds which indicate the site of a Roman camp, as aught but part and parcel of the primæval hill-side. So, M. Flourens, who believes that embryos are formed "tout d'un coup," naturally finds no difficulty in conceiving that species came into existence in the same way.

EMANCIPATION—BLACK AND WHITE

[1865]

QUASHIE's plaintive inquiry, "Am I not a man and a brother?" seems at last to have received its final reply—the recent decision of the fierce trial by battle on the other side of the Atlantic fully concurring with that long since delivered here in a more peaceful way.

The question is settled; but even those who are most thoroughly convinced that the doom is just, must see good grounds for repudiating half the arguments which have been employed by the winning side; and for doubting whether its ultimate results will embody the hopes of the victors, though they may more than realise the fears of the vanquished. It may be quite true that some negroes are better than some white men; but no rational man, cognisant of the facts, believes that the average negro is the equal, still less the superior, of the average white man. And, if this be true, it is simply incredible that, when all his disabilities are removed, and our prognathous relative has a fair field and no favour, as well as no oppressor, he will be able to compete successfully with his bigger-brained and smaller-jawed rival, in a contest which is to be carried on by thoughts and not by bites. The highest places in the hierarchy of civilisation will assuredly not be within the reach of our dusky cousins, though it is by no means necessary that they should be restricted to the lowest.

But whatever the position of stable equilibrium into which the laws of social gravitation may bring the negro, all responsibility for the result will henceforward lie between nature and him. The white man may wash his hands of it, and the Caucasian conscience be void of reproach for evermore. And this, if we look to the bottom of the matter, is the real justification for the abolition policy.

The doctrine of equal natural rights may be an illogical delusion; emancipation may convert the slave from a well-fed animal into a pauperised man; mankind may even have to do without cotton-shirts; but all these evils must be faced if the

moral law, that no human being can arbitrarily dominate over another without grievous damage to his own nature, be, as many think, as readily demonstrable by experiment as any physical truth. If this be true, no slavery can be abolished without a double emancipation, and the master will benefit by freedom more than the freed-man.

The like considerations apply to all the other questions of emancipation which are at present stirring the world—the multifarious demands that classes of mankind shall be relieved from restrictions imposed by the artifice of man, and not by the necessities of nature. One of the most important, if not the most important, of all these, is that which daily threatens to become the "irrepressible" woman question. What social and political rights have women? What ought they to be allowed, or not allowed, to do, be, and suffer? And, as involved in and underlying all these questions, how ought they to be educated?

There are philogynists as fanatical as any "miscegenists" who, reversing our antiquated notions, bid the man look upon the woman as the higher type of humanity; who ask us to regard the female intellect as the clearer and the quicker, if not the stronger; who desire us to look up to the feminine moral sense as the purer and the nobler; and bid man abdicate his usurped sovereignty over nature in favour of the female line.

On the other hand, there are persons not to be outdone in all loyalty and just respect for womankind, but by nature hard of head and haters of delusion, however charming, who not only repudiate the new woman-worship which so many sentimentalists and some philosophers are desirous of setting up, but, carrying their audacity further, deny even the natural equality of the sexes. They assert, on the contrary, that in every excellent character, whether mental or physical, the average woman is inferior to the average man, in the sense of having that character less in quantity and lower in quality.

Tell these persons of the rapid perceptions and the instinctive intellectual insight of women, and they reply that the feminine mental peculiarities which pass under these names are merely the outcome of a greater impressibility to the superficial aspects of things, and of the absence of that restraint upon expression which, in men, is imposed by reflection and a sense of responsibility. Talk of the passive endurance of the weaker sex, and opponents of this kind remind you that Job was a man, and

that, until quite recent times, patience and long-suffering were not counted among the specially feminine virtues. Claim passionate tenderness as especially feminine, and the inquiry is made whether all the best love-poetry in existence (except, perhaps, the "Sonnets from the Portuguese") has not been written by men; whether the song which embodies the ideal of pure and tender passion—"Adelaida"—was written by *Frau* Beethoven; whether it was the Fornarina, or Raphael, who painted the Sistine Madonna. Nay, we have known one such heretic go so far as to lay his hands upon the ark itself, so to speak and to defend the startling paradox that, even in physical beauty, man is the superior. He admitted, indeed, that there was a brief period of early youth when it might be hard to say whether the prize should be awarded to the graceful undulations of the female figure, or the perfect balance and supple vigour of the male frame. But while our new Paris might hesitate between the youthful Bacchus and the Venus emerging from the foam, he averred that, when Venus and Bacchus had reached thirty, the point no longer admitted of a doubt; the male form having then attained its greatest nobility, while the female is far gone in decadence; and that, at this epoch, womanly beauty, so far as it is independent of grace or expression, is a question of drapery and accessories.

Supposing, however, that all these arguments have a certain foundation; admitting, for a moment, that they are comparable to those by which the inferiority of the negro to the white man may be demonstrated, are they of any value as against woman-emancipation? Do they afford us the smallest ground for refusing to educate women as well as men—to give women the same civil and political rights as men? No mistake is so commonly made by clever people as that of assuming a cause to be bad because the arguments of its supporters are, to a great extent, nonsensical. And we conceive that those who may laugh at the arguments of the extreme philogynists, may yet feel bound to work heart and soul towards the attainment of their practical ends.

As regards education, for example. Granting the alleged defects of women, is it not somewhat absurd to sanction and maintain a system of education which would seem to have been specially contrived to exaggerate all these defects?

Naturally not so firmly strung, nor so well balanced as boys, girls are in great measure debarred from the sports and physical

exercises which are justly thought absolutely necessary for the full development of the vigour of the more favoured sex. Women are by nature more excitable than men—prone to be swept by tides of emotion, proceeding from hidden and inward, as well as from obvious and external causes; and female education does its best to weaken every physical counterpoise to this nervous mobility—tends in all ways to stimulate the emotional part of the mind and stunt the rest. We find girls naturally timid, prone to dependence, born conservatives; and we teach them that independence is unladylike; that blind faith is the right frame of mind; and that whatever we may be permitted, and indeed encouraged, to do to our brother, our sister is to be left to the tyranny of authority and tradition.

With few insignificant exceptions, girls have been educated either to be drudges, or toys, beneath man, or a sort of angels above him; the highest ideal aimed at oscillating between Clärchen and Beatrice. The possibility that the ideal of womanhood lies neither in the fair saint, nor in the fair sinner; that the female type of character is neither better nor worse than the male, but only weaker; that women are meant neither to be men's guides nor their playthings, but their comrades, their fellows and their equals, so far as nature puts no bar to that equality, does not seem to have entered into the minds of those who have had the conduct of the education of girls.

If the present system of female education stands self-condemned, as inherently absurd; and if that which we have just indicated is the true position of woman, what is the first step towards a better state of things? We reply, emancipate girls. Recognise the fact that they share the senses, perceptions, feelings, reasoning powers, emotions, of boys, and that the mind of the average girl is less different from that of the average boy, than the mind of one boy is from that of another; so that whatever argument justifies a given education for all boys justifies its application to girls as well.

So far from imposing artificial restrictions upon the acquirement of knowledge by women, throw every facility in their way. Let our Faustinas, if they will, toil through the whole round of

> "Juristerei und Medizin,
> Und leider! auch Philosophie."

Let us have "sweet girl graduates" by all means. They will be none the less sweet for a little wisdom; and the "golden

hair" will not curl less gracefully outside the head by reason of there being brains within. Nay, if obvious practical difficulties can be overcome, let those women who feel inclined to do so, descend into the gladiatorial arena of life, not merely in the guise of *retiarii*, as heretofore, but as bold *sicarii*, breasting the open fray. Let them, if they so please, become merchants, barristers, politicians. Let them have a fair field, but let them understand, as the necessary correlative, that they are to have no favour. Let nature alone sit high above the lists, "rain influence and judge the prize."

And the result? For our parts, though loth to prophecy, we believe it will be that of other emancipations. Women will find their place, and it will neither be that in which they have been held, nor that to which some of them aspire. Nature's old salique law will not be repealed, and no change of dynasty will be effected. The big chests, the massive brains, the vigorous muscles and stout frames of the best men will carry the day, whenever it is worth their while to contest the prizes of life with the best women. And the hardship of it is, that the very improvement of the women will lessen their chances. Better mothers will bring forth better sons, and the impetus gained by the one sex will be transmitted, in the next generation, to the other. The most Darwinian of theorists will not venture to propound the doctrine, that the physical disabilities under which women have hitherto laboured in the struggle for existence with men, are likely to be removed by even the most skilfully conducted process of educational selection.

We are, indeed, fully prepared to believe that the bearing of children may, and ought, to become as free from danger and long disability to the civilised woman as it is to the savage; nor is it improbable that, as society advances towards its right organisation, motherhood will occupy a less space of woman's life than it has hitherto done. But still, unless the human species is to come to an end altogether—a consummation which can hardly be desired by even the most ardent advocate of "women's rights"—somebody must be good enough to take the trouble and responsibility of annually adding to the world exactly as many people as die out of it.

In consequence of some domestic difficulties, Sydney Smith is said to have suggested that it would have been good for the human race had the model offered by the hive been followed, and had all the working part of the female community been

neuters. Failing any thorough-going reform of this kind, we see nothing for it but the old division of humanity into men potentially, or actually, fathers, and women potentially, if not actually, mothers. And we fear that so long as this potential motherhood is her lot, woman will be found to be fearfully weighted in the race of life.

The duty of man is to see that not a grain is piled upon that load beyond what nature imposes; that injustice is not added to inequality.

LECTURES ON THE STRUCTURE OF THE SKULL

I. THE STRUCTURE OF THE HUMAN SKULL

THE human skull is by no means one of the simplest examples of a vertebrate cranium which can be studied, nor is the comprehension of its structure easy; but, as all vertebrate anatomy has started from the investigation of human organisation, and the terms osteologists use are derived from those which were originally applied to definite parts of the organism of man, a careful investigation of the fundamental structure of man's skull, becomes an indispensable preliminary to the establishment of anything like a sound comparative nomenclature, or general theory, of the Vertebrate Skull.

Viewed from without (Fig. 1), the human cranium exhibits a multiplicity of bones, united together, partly by sutures, partly by anchylosis, partly by movable joints, and partly by ligaments; and the study of the boundaries and connections of these bones, apart from any reference to the plan discoverable in the whole construction, is the subject of the topographical anatomist, to whom one constantly observed fact of structure is as valuable as another. The morphologist, on the other hand, without casting the slightest slur upon the valuable labours of the topographer, endeavours to seek out those connections and arrangements of the bony elements of the complex whole which are fundamental, and underlie all the rest; and which are to the craniologist that which physical geography is to the student of geographical science.

Perhaps no method of investigating the structure of the skull conduces so much towards the attainment of a clear understanding of this sort of architectural anatomy, as the study of sections, made along planes which have a definite relation to the principal axes of the skull.

If a vertical and transverse section be taken through the cranium, in such a manner that the plane of the section shall traverse both external auditory meatuses, the skull will be

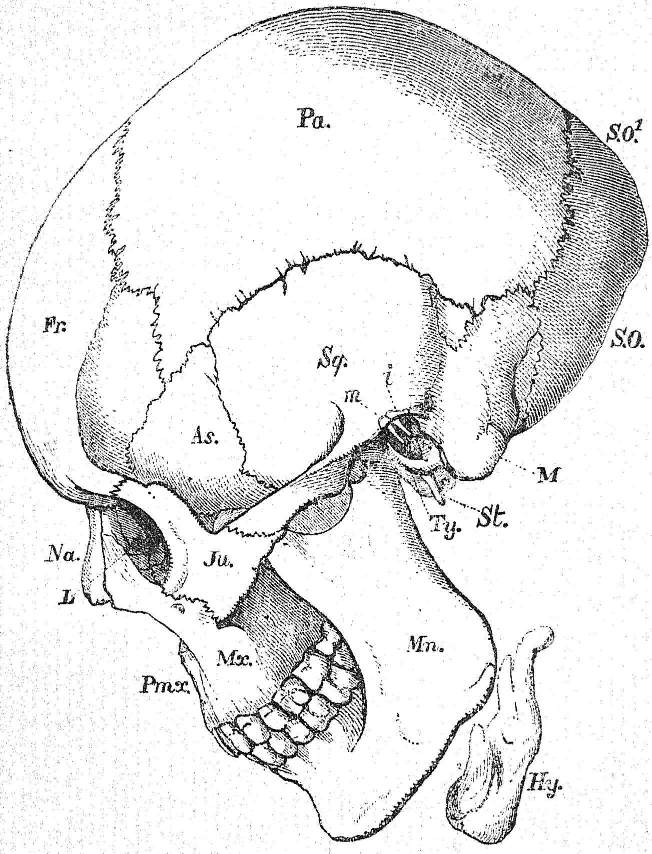


Fig. 1.—Diagrammatic side view of a Human Skull.—*Fr.* Frontal. *Pa.* Parietal. *S.O.* Supra-occipital. *S.O*[1]. *Squama occipitis* above the *torcular Herophili* and lateral sinuses. *As.* Alisphenoid. *Sq. Portio squamosa* of the temporal bone. *M.* Mastoid process and *pars mastoidea*. *Ty.* Tympanic. *St.* Styloid process. *Na.* Nasal. *L.* Lachrymal. *Ju.* Jugal, or Malar. *Pmx.* Premaxilla. *Mx.* Maxilla. *Mn.* Mandible. *Hy.* Hyoid. *m.* Malleus *i.* incus. [These letters will bear the same signification throughout the series of figures of crania.]

divided into two unequal portions—an anterior, larger, and a posterior, smaller. The former, if viewed from behind, will present the appearance represented in Fig. 2.

A stout median floor (*BS*) whence lateral continuations (*AS*) are prolonged to meet an arched roof (*Pa*), divides a capacious upper chamber, which, during life, lodged a part of the brain,

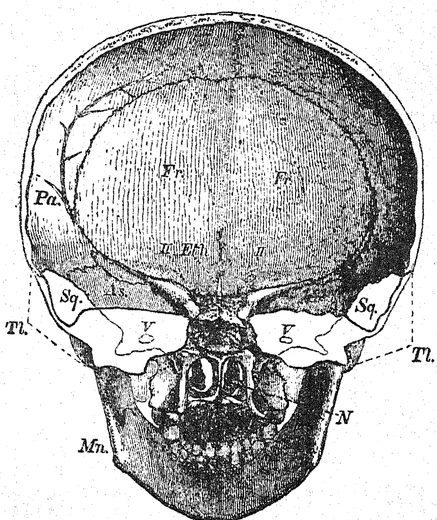


Fig. 2. Anterior half of the skull of a young person (six or seven years of age) transversely bisected. The temporal bone (*Tl*) on each side is left in outline, and the contour of the alisphenoid is supposed to be seen through it.—*II*, optic foramina between the roots of the orbito-sphenoids; *V*, *foramen ovale* for the third division of the trigeminal; *N* indicates the nasal chamber; *Mx* is placed in the buccal chamber.

from a lower chamber, formed by the bones of the face. This lower chamber itself is again separable into two parts,—an upper, divided into two by a median septum, the *nasal passages*; and a lower, the *oral cavity*.

The posterior portion of the bisected skull (Fig. 3) presents, in like manner, a strong floor (*BO*) and a large upper chamber for the lodgment of parts of the brain; but the lower chamber seems at first to be absent in the skeleton, being represented, in fact, only by the styloid processes (*St*), the so-called stylo-

hyoid ligaments, and the hyoidean bone (*Hy*) which is suspended by these ligaments to the skull.

A longitudinal and vertical section of the skull (Fig. 4) enables us to observe the same relations of the parts from another point of view. The central bones (*BO, BS, PS, Eth., Vo*), which lie between the arches of the brain-case above, and the arches of the face below, are, in such a section, found to constitute a

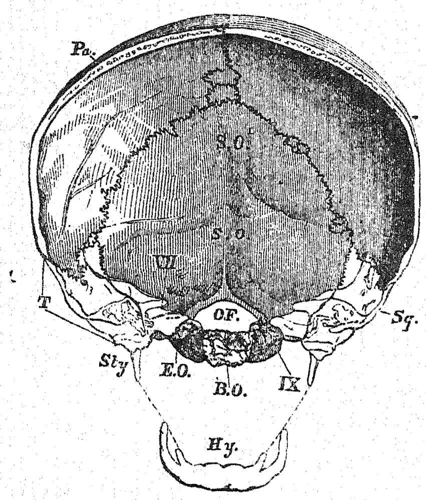


Fig. 3.—The posterior half of the transversely bisected skull, Fig. 2.—*B.O.*, the basi-occipital; *E.O.*, *E.O.*, the ex-occipitals; *T*, the temporal bone left in outline; *O.F.*, occipital foramen; *VII.*, canal for the portio dura and portio mollis; *IX.*, foramen for the ninth or hypoglossal nerve.

continuous series, from the occipital foramen to the anterior extremity of the nasal passage, which, as it forms the common centre or axis, not only for the bones of the brain-case or cranium proper, but also for those of the face, may be termed the *Cranio-facial axis.*

It will be useful to divide this axis into two portions,—a posterior *basi-cranial* (*BO, BS, PS*), which forms the centre of the floor of the proper cranial cavity; and an anterior, *basi-facial* (*Eth., Vo*), which constitutes the axis of the front part of the face.

Three pairs of chambers, destined for the lodgment of the

organs of the higher senses, are placed symmetrically upon each side of the double bony box thus described. Of these, two pair

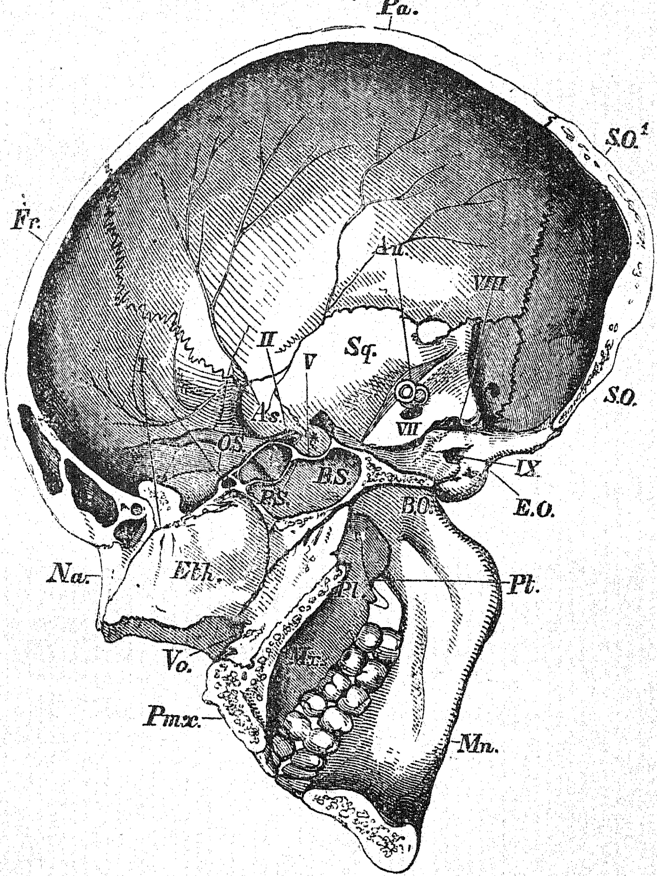


Fig. 4. Longitudinal and vertical section of a Human Skull.—* The *sella turcica*. *Au.* The position of the superior and posterior vertical semicircular canals. I., II., V., VIII., IX. The exit of the olfactory, optic, third division of the fifth, eighth, and ninth nerves. *Vo.*, the Vomer.

are best seen in a front view of the skull (Fig. 5), the inner pair being the *olfactory*, or *nasal chambers* (N), the outer pair, the *orbits* (*Or*). The other pair are better displayed in the transverse sections, Fig. 2 and Fig. 3, and are formed by the temporal bones of anatomists (*T*, *Tl*), and especially by the petrous and mastoid portions of those bones.

There is an obvious difference between the relations of these sensory chambers to the contained sensory organ, in two of

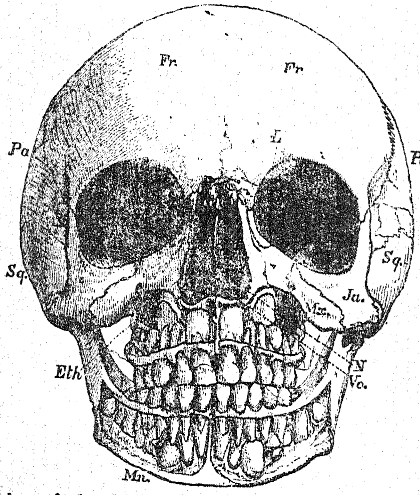


Fig. 5. Front view of the skull, the halves of which are shown in Figs. 2 and 3.—*N*, nasal chamber; *Or*, orbit. The nasal bones are removed, and so much of the upper and lower jaws as is necessary to show the permanent teeth.

these chambers as compared with the third. The sensory apparatuses of the nose and of the ear are firmly fixed to, or within, the bony chambers in which they are lodged. That of the eye, on the other hand, is freely movable within the orbit.

An axis, upper and lower arches, chambers for the sensory organs—such are, speaking generally, the components of the skull. The special study of these components may be best commenced from the cranio-facial axis. Viewed either from above (Fig. 6) or from below (Fig. 7), the cranio-facial axis is seen to be depressed, or flattened from above downwards, behind,

and thick and nearly quadrate in the middle; while, in front, it is so much compressed, or flattened from side to side, that it takes the shape of a thin vertical plate. In such a young skull as that from which the Figures 6 and 7 are taken, the depressed hindermost division of the axis is united with the rest, and with the bones *EO, EO,* only by synchondroses; and is readily separable, in the dry skull, as a distinct bone, which is termed the *Basi-occipital* (*BO*). This basi-occipital furnishes

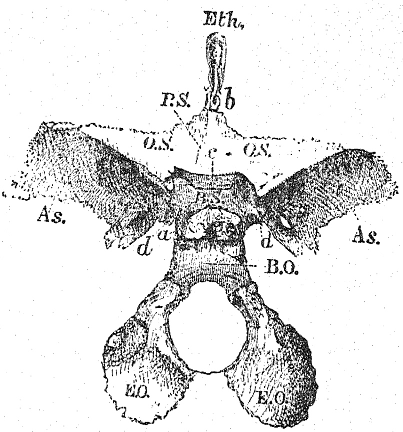


Fig. 6. Cranio-facial axis and lateral elements of the superior arches of a human skull viewed from above.—*a*, the spheno-occipital synchondrosis; *b*, the ethmo-sphenoid synchondrosis; *c*, the *tuberculum sellæ*, indicating the line of demarcation between the basi-sphenoid and the presphenoid; *d*, the *lingulæ sphenoidales*.

the front boundary of the occipital foramen; and its postero-lateral parts, where they abut against the bones *EO*, contribute, to a small extent, to the formation of the two occipital condyles. In the adult skull the basi-occipital anchyloses completely with the ex-occipital, on the one hand, and with the next bone of the basi-cranial axis on the other, so that the saw must be called to our aid in order to demonstrate the bone.

From the synchondrosis *a* to the point *b*, in even so young a skull as that here represented, the basi-cranial axis is formed by one continuous ossification, the *Basi-sphenoid* bone, excavated superiorly (Figs. 4 and 6) by a saddle-shaped cavity,

the *sella turcica*, which lodges the pituitary body,—an organ of no great physiological moment, so far as we know, but of first-rate morphological significance.

On each side of the hinder part of the *sella turcica*, the basi-sphenoid presents a groove for the internal carotid artery, and this groove is completed in front and externally, by an osseous mass, tapering from behind forwards, the *lingula sphenoidalis*, which lies between the basi-sphenoid and alisphenoid. At the

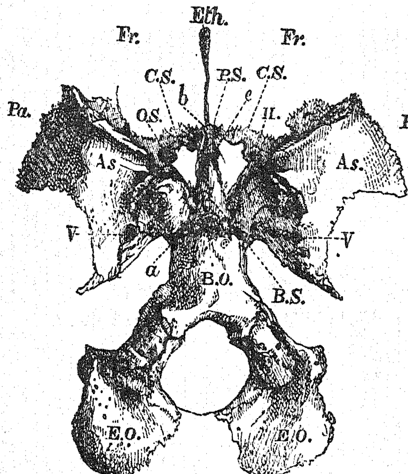


Fig. 7. Cranio-facial axis and lateral elements of the superior arches (as in Fig. 6), with the pterygoid bones, and without the vomer, viewed from below.—*e*, junction of the basi-sphenoid and presphenoid with the internasal cartilage; *C.S.*, *cornua sphenoidalia*, or bones of Bertin.

front part of the *sella*, separating it from the depression for the optic commissure, there is a transverse ridge, the *tuberculum sellæ*.[1] The region between the synchondrosis and the tuberculum is the upper surface of the *basi-sphenoid*. Its under-surface (Fig. 7) exhibits a median, wedge-shaped portion, terminating abruptly at the point *e*, on each side of which are stuck on, as it were, two delicate bones, shaped somewhat like

[1] Where the terms employed in our ordinary handbooks of Human Anatomy do not suffice for my purpose, I adopt those used by Henle in his classical "Handbuch der Systematischen Anatomie des Menschen," a work of great accuracy and comprehensiveness, now in course of publication.

sugar-bags, with their wide and open ends directed forwards and their apices backwards. These are the bones of *Bertin*, or *cornua sphenoidalia*, which do not properly belong to the basi-sphenoid, but coalesce with it in the course of growth.

From the *tuberculum sellæ* (*c*) to the point (*b*) in the upper view (Fig. 6), and from the point *e*, to *b* of the lower view (Fig. 7), the middle region of the cranio-facial axis belongs to a third bone, the *presphenoid* (*PS*) which terminates the basi-cranial axis.

I say *terminates* the basi-cranial axis, because the appearance of a continuation forwards of that axis by the *crista galli*, or upper margin of the *lamina perpendicularis* of the ethmoid (see Fig. 4), is altogether fallacious, depending, as it does, upon a special peculiarity of the highest Mammalian skulls, which arises from the vast development of the cerebral hemispheres. In the great majority of *Mammalia* below the Apes, in fact, the free edge of the *lamina perpendicularis* is not horizontal, but greatly inclined, or even vertical; and in these cases the whole *lamina* plainly appears to be, what it really always is, beyond, or anterior to, the floor of the brain-case; while the true basi-cranial bones are parts of the floor of the brain-case.

During fœtal life, the basi-sphenoid and presphenoid are united only by synchondrosis, traces of which may even be discovered (as Virchow has shown) as late as the thirteenth year, or later. Even before birth the two bones become anchylosed superiorly, their junction being marked by the *tuberculum sellæ*; and the remains of the synchondrosis extend obliquely from this spot, downwards and forwards, to the point *e* (Fig. 7) on the under-surface of the axis, where its cartilage becomes continuous with the osseo-cartilaginous internasal septum.

It is this osseo-cartilaginous septum between the two nasal cavities, the upper free edge of which constitutes the *crista galli*, while the lower free edge supports the *septum narium*, which terminates the *basi-facial axis*.

All the upper and middle part of this septum is formed by a thin osseous plate, the *lamina perpendicularis* of human anatomy, or true *Ethmoid* (*Eth.*), which abuts, in front, upon the frontal and nasal bones; behind, upon the presphenoid; and below, upon a rod-like mass of cartilage, which becomes connected with the *septum narium* and the premaxillary bones anteriorly and inferiorly, and is obliterated with age.

The inferior and posterior part of the septum is constituted

by a bone with a gutter-like upper and anterior boundary, which embraces the whole rounded inferior and posterior edge of the cartilage in question, and thus extends from the under-surface of the basi-sphenoid, posteriorly and superiorly, to the middle of the roof of the bony palate, anteriorly and inferiorly. This bone is the *Vomer* (*Vo.*, Fig. 4).

Thus there are three bones in the *basi-cranial axis*,—the basi-occipital, basi-sphenoid, and presphenoid; and there are two bones in the *basi-facial* axis,—the ethmoid and the vomer; the essential difference between these two sets of bones being that the former constitute the middle part of the floor of the brain-case, while the latter are altogether excluded therefrom.

We may now turn to the upper arches of the skull, or those bones which form the walls and roof of the brain-case. In the young skull from which the Figures 6 and 7 are taken, the postero-lateral margins of the basi-occipital are united with the rest of the occipital bone, only by synchondrosis. The parts of the latter which are thus united with the basi-occipital, and which limit the sides of the great occipital foramen, are primitively distinct bones,—the *Ex-occipitals* (*Eo.*); while the squamous part, which bounds the posterior segment of the foramen, is known as the *Supra-occipital* (*So*, *So*[1]). All these bones, eventually becoming anchylosed together, form the occipital bone of the human anatomist; or what we may term the first, posterior, or *Occipital segment* of the skull.

From the sides of the basi-sphenoid, external to the *lingulæ*, two wide processes, well-known as the "greater wings of the sphenoid" or *Alisphenoids* (*AS*) spring, and unite suturally with the expanded *Parietal* bones (*Pa*), which form the dome-like crown of the skull, and unite in the middle line in the sagittal suture. In this way a second, middle, or *Parietal segment* of the skull is distinguishable.

In like manner, the presphenoid passes, on each side, into the smaller processes, the "lesser wings of the sphenoid," *alæ minores*, or wings of Ingrassias; which, on account of their relations to the orbits, have been well named the *Orbito-sphenoids* (*OS*). And these, externally and anteriorly, unite by suture with the arched and expanded *Frontal* bones (*Fr*), originally double, and separated by a median frontal suture, which ordinarily early disappears. These bones not only meet in front, but send in processes which roof over the orbits and

unite with the free anterior edges of the orbito-sphenoids, thus leaving only a long and narrow vacuity, on each side of the *crista galli*, and in front of the presphenoid.

The presphenoid, the orbito-sphenoid, and the frontals are the constituents of the third, anterior, or *Frontal segment* of the skull.

It will be observed, however, that this enumeration of the bones of the three great segments of the skull does not account for all the distinct osseous elements, which enter, directly and indirectly, into its boundaries. If all the bones mentioned are put together, there still remain four considerable vacuities; two small, already mentioned, in the proper front wall of the skull, on each side of the *crista galli*; and one on each side, posteriorly, between the occipital and parietal segments, of very much larger size, and extremely irregular form. The anterior vacuities are filled up by those spongy osseous masses, united with the *lamina perpendicularis* in the adult skull, which are called "lateral masses of the Ethmoid," or "superior and middle spongy bones," and more immediately by the perforated cribriform plate, which allows of the passage of the filaments of the olfactory nerve, and connects these lateral masses with the *lamina perpendicularis*, or proper ethmoid. Looking at the bones which form the immediate walls of the upper and middle part of the nasal chambers, with reference only to the olfactory organs, we might say, in fact, that the anterior vacuity of the cranium proper is stopped by the ossified walls of the olfactory sacs, consisting of the ethmoid and vomer in the middle line, of the superior and middle spongy bones (or so-called lateral masses of the ethmoid) supero-laterally, of the inferior turbinal bones infero-laterally. And to these ossifications must be added, as members of the olfactory group, the bones of Bertin, posteriorly and superiorly, and the nasal bones, anteriorly and superiorly.

The great posterior vacuity on each side is filled up by the *Temporal bone*, which consists of a very considerable number of distinct elements, only distinguishable by dissection and by the study of development in Man, but which remain permanently distinct, and undergo very strange metamorphoses in many of the lower Vertebrates. Some of these constituents of the temporal bone, such as the squamous portion or *Squamosal* (*Sq.*), and the *Malleus*, *Incus*, and *Stapes*, are discriminated by the student of ordinary human anatomy; but there are many others which he is not in the habit of regarding as distinct

osseous elements. Thus the bony "external auditory meatus" is primitively a distinct bone, termed *Tympanic* (*Ty.*) on account of its affording the frame in which almost the whole of the tympanic membrane is set. The *Styloid* process (*St.*) is originally a distinct bone. And, lastly, the *pars petrosa* and *pars mastoidea* of human anatomy are, in reality, made up of three distinct ossifications, of which I shall have to say more presently, but which I shall speak of for the present under the collective name of the *Periotic* bones, because they immediately surround the organ of hearing.

Not merely the periotic, but also the squamosal and tympanic bones are so closely related to the auditory organ, that the postero-lateral apertures of the cranium may be said to be stopped by the osseous chambers of the auditory organ, in the same way as the anterior apertures are closed by the osseous chambers of the olfactory organs. As the eye is contained only in a mobile fibrous capsule, the sclerotic, the apertures which lead to the orbit—the spheno-orbital fissures and the optic foramina—are not closed by any special bones pertaining to the sensory organ lodged therein.

Thus the brain-case may be said to be composed of three superior arches connected respectively with the three divisions of the basi-cranial axis, and of two pair—an anterior and a posterior—of bony sense capsules interposed between these arches. A middle, third pair of sense capsules is not represented by bone in the cranial walls.

In like manner, the face may be resolved into a series of bones, occurring in pairs from before backwards, and forming more or less well-defined lower arches, some of which embrace the nasal cavity, being placed in front of, or above, the oral aperture, while others enclose the buccal chamber, and are situated behind and below the oral aperture. Of the former, *pre-oral* bones, there are four pairs—the *Premaxillæ* (*Pmx.*), the *Maxillæ* (*Mx.*), the *Palatines* (*Pl.*), and the *Pterygoids* (*Pt.*).

The *Premaxillæ*, which lodge the upper incisor teeth, so early lose their distinctness in man, by becoming anchylosed with the maxillary bones (at any rate externally and anteriorly) that they are rarely recognised as separate bones. Nevertheless, a suture extending upon the bony palate from the posterior margin of the alveolus of the outer incisors to the incisive foramen, very commonly persists, as an indication of the primitive separation of these bones. The most important character of the premaxillæ,

regarded morphologically, is, that they are connected, superiorly, with the anterior termination of the cranio-facial axis, and that this connection is a primary one. Each premaxilla passes from its inner end, which is united with the axis, outwards and backwards, and two of the other three pair of pre-oral bones have similar relations to the cranio-facial axis. The anterior of these are the *Palatine* bones; the inner, or sphenoidal, processes of which are connected with the basi-sphenoid and with the vomer; while the outer, or orbital, processes articulate with the so-called lateral masses of the ethmoid and with the maxilla; so that the upper part of each palatine bone is directed, from the cranio-facial axis, with which its inner end is connected, outwards and forwards (Fig. 8). The third pair of bones, the *Pterygoids*, are the internal pterygoid processes,—bones which are originally quite distinct from the sphenoid, while the external pterygoid processes are of a very different character, being mere outgrowths of the alisphenoids. These are connected with the basi-sphenoid (or rather with the *lingulæ sphenoidales*), above, and, in front, with the palatines, while their planes are directed backwards and somewhat outwards. The fourth pair of pre-oral bones—the *Maxillæ*—are connected in front and internally with the premaxillæ, and behind and internally with the palatines, but they nowhere come into direct contact with the cranio-facial axis, at least primarily.

I make the latter qualification because the vomer articulates with the superior surface of the palatine plates of the maxillæ, and it may be said that, in this way, the maxillæ do unite with the cranio-facial axis. This articulation, however, has nothing to do with the primitive connections of the bones, but depends upon a modification of the maxillæ peculiar to the higher vertebrata. The bony apertures—called "posterior nares"—in Man, for example, are structures of a totally different character from, and superadded to, what are called the posterior nares in a frog, or ordinary lizard, or bird. In these lower Vertebrates, the posterior nares are apertures, bounded, on the inner side, by the vomer; on the outer side and behind, by the palatine bones; in front, by the premaxillæ and maxillæ. In Man, on the other hand, the apertures so called are limited, it is true, on the inner side by the vomer, and on the outer side by the palatine bones; but they are also bounded below and in front by the palatine bones, and the premaxillæ and maxillæ have nothing to do with them. On looking closely into the matter, however, it will be

found that that region of the palatine which forms the outer and inferior boundary of the posterior nares of Man is a something which has no representative in the lower Vertebrate.

But if, with a fine saw, the greater part of the perpendicular plate of the palatines, and the corresponding part of the maxillaries, and, with these, their palatine plates, be cut away, leaving only the premaxillæ, vomer, and upper parts of the maxillary and palatine bones; it will be found that hinder nares are left,

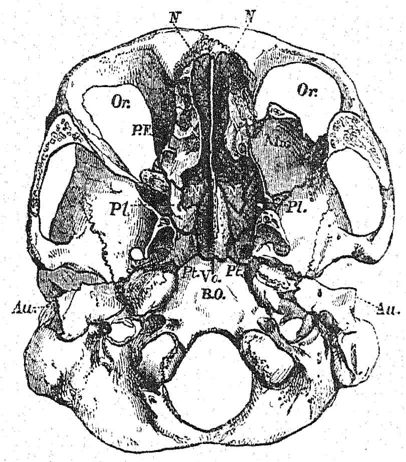


Fig. 8.—The base of a human skull—the nasal, ethmoid, vomerine, maxillary, palatine, and pterygoid bones being cut through horizontally, and their lower portions removed. The entire right maxilla is taken away. The posterior pair of letters, *NN*, are situated in the median nares, which are incomplete, in front, in consequence of the removal of the premaxillæ.

which entirely correspond with the "posterior nares" of a bird or of an amphibian; that is to say, they are passages between the vomer in the middle line, the premaxillæ and maxillæ in front and externally, and the palatines externally and behind.

In fact, the apertures of the nasal chamber into the mouth, thus artificially exposed, are those which originally exist in Man and the higher *Vertebrata;* but the downward growth of the maxilla into its alveolar process, and of the palatine bone into its perpendicular plate, together with the production inwards of the palatine plates of these bones, which eventually unite with

the vomer, give rise to the apertures, which are ordinarily called posterior nares. So that in Man, for example, there are three pairs of "nares:"—the *external,* situated between the anterior end of the internasal septum, the nasal bones, and the premaxillæ, as in the lower Vertebrates; the *median,* between the vomer, the palatines, and the premaxillæ, which correspond with the posterior nares of the lower Vertebrates; and the *posterior,* between the vomer, internally, and the palatines above, at the sides, and below, which are peculiar to the higher Vertebrates.

And, to return to the maxilla, we find that it really differs altogether from the other pre-oral bones, and is, as it were, fastened on to the outer sides of the premaxillary and palatine bones, without having any primary direct connection with the cranio-facial axis.

The *post-oral* bones surround the buccal cavity, and form two distinct arches—the *mandibular* and the *hydoidean.* Neither of these arches is directly connected with the cranio-facial axis, nor with the segments of the brain-case, but both are suspended to different parts of the temporal bone, which is so singularly intercalated between the middle and posterior of those segments.

The lower jaw or *Mandible* (*Mn*) consists of two rami, anchylosed at the symphysis, and each consisting of a single piece, the condyle of which articulates with the squamosal.

The *Hyoid* bone (*Hy*), composed of its body and two pairs of cornua, does not articulate directly with the temporal bone, but ligaments connect it with the styloid processes, and these last bones unite with the posterior part of the periotic capsules.

Thus, the natural connections of the bones by no means allow of the separation of the walls of the lower chambers of the human skull into a series of arches springing from, and corresponding with, the axial parts, as we found to be the case with the walls of the upper chambers.

If the temporal bone be detached, the hyoidean and mandibular arches come with it, and exhibit no connection with the occipital or the parietal segments. Indeed, the latter is preoccupied by the pterygoid and the palatine, both of which are connected with the basi-sphenoid (at least with the *lingulæ*), while the anterior part of the palatine is also connected, in the adult state, with the presphenoid, by the intermediation of the *cornua sphenoidalia.*

Two bones yet remain to be mentioned which come neither

into the category of axial bones, nor of superior or inferior arch bones, nor, strictly speaking, of sense-capsule bones. These are the *Lachrymal* (*L*), intercalated between the nasal, maxillary, and lateral mass of the ethmoid, and serving to lodge the conduit which places the orbit and the nasal cavity in communication; and the *Jugal* or *Malar* (*Ju*), which connects the bones of the orbital chamber with the squamosal element of the temporal bone.

The skull, thus composed, serves as a protection to the organs which are lodged within it, and which are of as great importance in their morphological, as in their physiological, aspect.

The cerebral hemispheres and cerebellum, with their dependent parts, fill the cranial cavity, the lower lateral margin of the posterior cerebral lobes corresponding with the *torcular Herophili* and the lateral sinuses, on the inner surface of the occipital bone; or, in other words, with the line of attachment of the tentorium. Certain axial parts of the brain have definite relations to the axial parts of the cranium. Thus, the medulla oblongata lies upon the basi-occipital. The pituitary body rests upon the upper surface of the basi-sphenoid, this bone constituting the chief part of the front as well as of the hinder wall of the *sella turcica*. The *chiasma* of the optic nerves rests upon the hinder portion of the upper face of the presphenoid, and the peduncles of the olfactory nerves upon the front portion of that face. The termination of the axial parts of the brain in the *lamina terminal.s* of the third ventricle corresponds pretty nearly with the termination of the basi-cranial axis in the anterior extremity of the presphenoid.

Not less important are the relations of many of the cerebral nerves to the lateral elements of the arches of the brain-case.

The filaments of the olfactory nerves pass out through the cribriform plates, leaving the ethmoid proper, or *lamina perpendicularis*, upon their inner side, and the lateral masses of the ethmoid, or superior and middle spongy bones, upon their outer sides.

The optic nerves pass out through the optic foramina, situated between the roots of the orbito-sphenoids, from the *chiasma*, which rests, as has just been stated, upon the posterior and upper part of the presphenoid. Hence it follows, that the presphenoid lies in front of, and between, the optic nerves, which embrace it, as in a fork, from behind.

The third and fourth pairs are not of so much morphological importance that I need dwell upon them, but the trigeminal affords first-rate cranial landmarks by its nasal branch and its whole third division. The nasal nerve enters the orbit by the *foramen lacerum anterius*, passes to the inner side of the eye, and then, traversing the anterior of the two ethmoidal foramina, perforates the "lateral mass of the ethmoid," and entering the cavity of the bony cranium, though it always lies beneath the dura mater, skirts the olfactory aperture, and passes out into the nasal cavity, by an aperture in the front part of the cribriform plate. We shall find this irregular perforation of the "lateral mass of the ethmoid," by the nasal division of the fifth nerve, to be an excellent guide to the determination of the homologue of the bone in the lower *Vertebrata*.

The third divison of the trigeminal traverses the *foramen ovale* in the posterior part of the alisphenoid, so that it makes its exit behind the greater part of that bone, and altogether in front of the periotic bone.

The *portio dura* enters the internal auditory foramen in the periotic mass, runs along its canal, situated above the *fenestra ovalis*, and eventually passes out by the stylo-mastoid foramen. It therefore perforates the fore part of the periotic, passing in front of the membranous labyrinth. The *portio mollis* also enters the periotic bone by the internal auditory foramen, and it terminates in the membranous labyrinth.

The eighth pair passes out through the *foramen lacerum posterius* completely behind the periotic (which thus lies between the exits of the fifth and of the eighth pairs), and in front of the ex-occipitals.

The ninth pair perforates the ex-occipitals in front of the condyles.

With regard to the relations of the nerves to the inferior arches of the skull, only one circumstance calls for particular notice—the distribution of the terminal divisions of the *portio dura*. This nerve divides, as it is about to leave the temporal bone, into two portions, the larger of which passes out by the stylo-mastoid foramen, and, besides giving off many other branches, supplies certain muscles of the hyoidean apparatus.

The smaller division of the nerve, of comparatively insignificant size—the *chorda tympani*—returns to the tympanic cavity, crosses it, and leaving it by an aperture internal to, and above the tympanic element, runs down upon the inner side of the

lower jaw. In Man, the great development of the facial muscles gives a predominance to the branches of the *portio dura* which supply them; but, in the lower Vertebrates, the nerve becomes more and more completely represented by simple mandibular and hyoidean divisions, corresponding respectively with the *chorda tympani* and the branches distributed to the stylo-hyoid and digastric.

In the preceding description of the architecture of the human skull, I have, as far as possible, avoided complicating the general view of its structure which I have desired to give, by entering into any details which were not strictly necessary; but there remains one part of the cranium—the temporal bone—the structure of which must be carefully and thoroughly investigated, if we desire to understand the modifications undergone by the bones which correspond with its constituent elements in other *Vertebrata*.

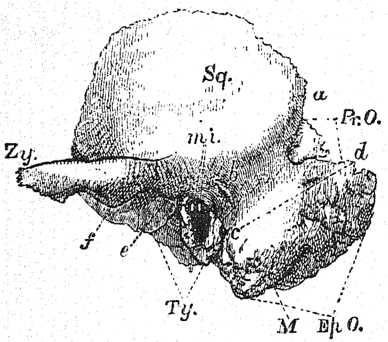


Fig. 9.—Human left temporal bone, half the natural size.—*a b*, posterior root of the zygomatic process; *e*, middle root; *f*, anterior root; *b*, post-auditory fossa; *m i*, long processes of the malleus and of the incus.

Viewed from without, the temporal bone presents the well-known *pars squamosa* (*Sq.*) and *pars mastoidea* (*M*), in the re-entering angle between which the tympanic element (*Ty.*) is fixed (Fig. 9).

No suture separates the *pars squamosa* from the *pars mastoidea*, but the posterior limits of the former are indicated, in the first place, by the curved ascending portion of the posterior root of the zygoma (*a b*), which bounds the attachment of the temporal muscle; and, secondly, by a curved ridge, convex backwards and differently defined in different subjects—the *margo tympanicus* of Henle—which passes downwards behind the auditory meatus, until it cuts the contour of the tympanic bone. Near the upper end of this ridge, or "post-auditory process," is an elongated "post-auditory fossa" (*b*), more marked in old than in young subjects.

The portion of the squamosal element, the free edge of which terminates in this ridge, forms an arch, of which the posterior pillar constitutes the posterior and upper wall of the auditory meatus, while the anterior pillar forms the front boundary of the glenoid cavity. The centre of the arch is interrupted by the middle root of the zygoma (*e*), or "the post-glenoidal process" of the squamosal, which runs, as a wedge-shaped ridge, transversely to the span of the arch.

The upper edge of the anterior wall of the gutter-shaped tympanic bone (which forms the hinder boundary of the glenoid cavity), unites with this ridge, crossing its direction obliquely inwards and forwards. Beyond the ridge it is no longer united with the squamosal, but, keeping its oblique direction, crosses rather to the inner side of the lower edge of that bone, and leaves the Glaserian fissure between the squamosal and itself.

A section taken through both the external and the internal auditory meatuses (Fig. 10) shows that this arched plate of the squamosal is interposed between the upper half of the tympanic and the upper parts of the *pars petrosa* and *pars mastoidea*, the depth of the interposed squamosal being greatest posteriorly, while it diminishes to nothing anteriorly.

The upper region of the *pars petrosa*, however, does not directly abut, by its thick mass, against the squamosal, but by a thin horizontal plate, which roofs over the tympanum, the Eustachian tube, and the *antrum mastoideum* and is the *tegmen tympani*.[1]

The lower region of the *pars petrosa* in like manner gives off a thicker and shorter plate, which forms the floor of the Eustachian tube and the outer or inferior boundary of the carotid canal, in front; the floor of the tympanum, in the middle; and then, becoming gradually thicker, constitutes the lower boundary of the *antrum mastoideum*. It is with the outer edge of this inferior, or floor-plate, of the tympanum that the lower portion of tympanic bone becomes anchylosed. The inner wall is of course constituted by the outer surface of the more massive part of the *pars petrosa*. Thus, the roof and part of the floor of the tympanum are formed by the superior and inferior prolongations of the *pars petrosa*, while the outer wall of the tympanum is constituted above by the squamosal, and below by the tympanic. A section taken vertically and transversely to the axis of the skull through the middle of the *fenestra ovalis*, in the way

[1] It lies immediately beneath the letters *Pr.O.*, Fig. 10 A.

described above, shows that the squamosal limits, externally, an upper chamber of the tympanum (*b*, Fig. 10), which is nearly as deep as, and is wider than, the lower division, bounded externally

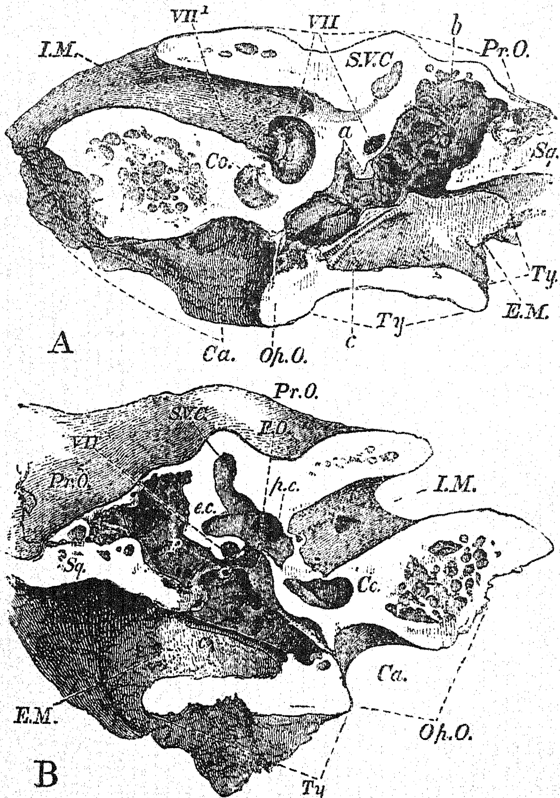


Fig. 10.—Views of the petrous and tympanic portions of the right temporal bone of the skull represented in Figs. 2 and 3, magnified two diameters.—*A*, the anterior half of the bone; *B*, its posterior half; *I.M.*, internal meatus; *E.M.*, external meatus; *a*, processus cochleariformis; *b*, chamber in which the heads of the malleus and incus lie; *c*, groove for the tympanic membrane; *S.V.C.*, superior vertical semicircular canal; *e.c.*, external semicircular canal; *p.c.*, posterior vertical semicircular canal; *Co.*, cochlea; *P*, Pyramid; *F.O.*, fenestra ovalis; *VII*, canal for portia dura; *VII*¹, for portio mollis.

by the tympanic membrane and tympanic bone (Fig. 10). It is in this upper chamber that the heads of the malleus and incus are lodged, the handle of the one and the long process of the other, only, depending into the proper tympanic cavity. Hence, in looking into the tympanum from without (Fig. 9) when the ear-bones are *in situ*, only these processes are seen, the heads of both malleus and incus being hidden by the arched plate of the squamosal.

Thus, the tympanum is formed by a very complicated adjustment of bony elements, and we shall by and by see reason to believe that it is even more complex than it now appears to be, inasmuch as the so-called *pars petrosa* will prove to be composed of two distinct elements; an inferior, *opisthotic*, bone, containing the lower part of the cochlea, and a superior, *pro-otic*, sheltering the greater part of the vestibule, the upper part of the cochlea, the anterior vertical semicircular canal, part of the posterior vertical canal, and the external semicircular canal.

Behind the posterior boundary of the squamosal, constituted by the two diverging lines above described (Fig. 9), lies all that portion of the temporal bone which is known as the *pars mastoidea*. But, as I shall have occasion to demonstrate, when explaining the mode of development of the temporal bone, this *pars mastoidea* is, in reality, made up of extensions of two of the primitive constituents of the *pars petrosa*, and of a third element, the *epiotic*. The posterior margin of the squamosal, as above described, may be said roughly to form two sides of a parallelogram. The third side is the thick part of the upper edge of the *pars mastoidea*, corresponding with the termination of the upper and anterior surface of the *pars petrosa* on the inner side of the bone. If a fourth side is made by an imaginary line connecting the ends of the others, the bony surface which lies above and in front of the line will, as nearly as possible, belong to the *pro-otic* element, while that which lies below and behind it, including the mastoid process, appertains to the *epiotic*. On the other hand, a certain amount of the *pars mastoidea* internal to the digastric groove belongs to the *opisthotic*.

II. THE DEVELOPMENT OF THE HUMAN SKULL

As might be expected from the nature of the case, it has not yet been possible to obtain a series of human embryos, in every stage of development, sufficiently large to enable embryologists to work out all the details of the formation of the human skull. But all higher vertebrate embryos so nearly follow one and the same type of early developmental modification, that we may reason, with perfect confidence, from the analogy of the lower Vertebrates to man, and fill up the blanks of our observations of human embryos by investigations of the chick, the dog, the rabbit, or the pig.

In the chick, the first indication of the body of the embryo is an elongated, elevated area of the blastoderm, the axis of which is traversed by a linear groove. The one end of the elongated area is wider and more distinctly raised up from the rest of the blastoderm, than the other: it is the cephalic end, and the linear groove stops short of the rounded extremity of this part of the elevated area. A peculiar cellular cylinder, tapering off at each end, the notochord, is soon discerned occupying the bottom of this groove, beneath the outer, serous, or neuro-epidermic layer of the germ.

A laminar outgrowth of the convex summits of the ridges which bound the primitive groove now takes place, in that part of the embryo, which will eventually become the middle region of the head; and the *dorsal laminæ*, thus produced, extending forwards and backwards, like parapets, upon each side of the primitive groove, lay the foundations of the lateral walls, not only of the skull, but of the spinal column.

Very early, however, the boundary line between skull and spinal column is laid down, by the appearance in the substance of the bases of the dorsal laminæ and the adjacent middle layer of the blastoderm, of the first pair of those quadrate masses of condensed tissue, the *proto-vertebræ* ("Urwirbel" of the German writers), which are the foundations, not only of the bodies of the vertebræ, but of the spinal muscles and ganglia. The proto-vertebræ increase in number from before backwards; and, at length, extend through the whole range of the spinal

column, while none ever make their appearance in the region which will be converted into the skull.

The edges of the dorsal laminæ now unite, the coalescence taking place first in the middle cephalic region, and extending thence backwards and forwards; at the same time, the cephalic canal becomes separated into three distinct dilatations, or cerebral vesicles, of which the anterior is by far the most marked (Fig. 11, A, *I, II, III*).

The rudimentary cranial cavity next becomes bent upon itself in such a manner, that the longitudinal axis of the first cerebral vesicle takes a direction at right angles to the axis of the third, and of the spinal canal generally. In consequence of this change, the middle cérebral vesicle occupies the summit of the angulation, and becomes the most anterior point of the whole body (Fig. 11, C, D).

The bend thus produced is the *cranial flexure*. It results in the division of the floor of the cranial cavity into two parts, an anterior and a posterior, which are at right angles to one another (Fig. 11, C, D, E). Hitherto, no trace of the notochord has been observed in the anterior division, that structure ending in a point behind the flexure (Fig. 11, D, E, *h*).

As development proceeds, the anterior cerebral vesicle becomes divided into two portions—an anterior, the vesicle of the cerebral hemispheres (I^a); and a posterior, the vesicle of the third ventricle (I^b). In the upper wall of the vesicle of the third ventricle the rudimentary pineal gland (*e*) makes its appearance in the middle line. From the middle of the lower wall grows out a process, the *infundibulum*, terminating in a glandular appendage, the pituitary body, which last is lodged in the deep fossa situated in the floor of the anterior division of the skull, immediately in front of, and beneath, the termination of the notochord (Fig. 11, B, D, *d*).

The three pairs of sensory organs appertaining to the higher senses—the nasal sacs, the eyes, and the ears—arise as simple cæcal involutions of the external integument of the head of the embryo. That such is the case, so far as the olfactory sacs are concerned, is obvious; and it is not difficult to observe that the lens and the anterior chamber of the eye are produced in a perfectly similar manner. It is not so easy to see that the labyrinth of the ear arises in this way, as the sac resulting from the involution of the integument is small, and remains open but a very short time (Fig. 11, C, *b*). But I have so frequently

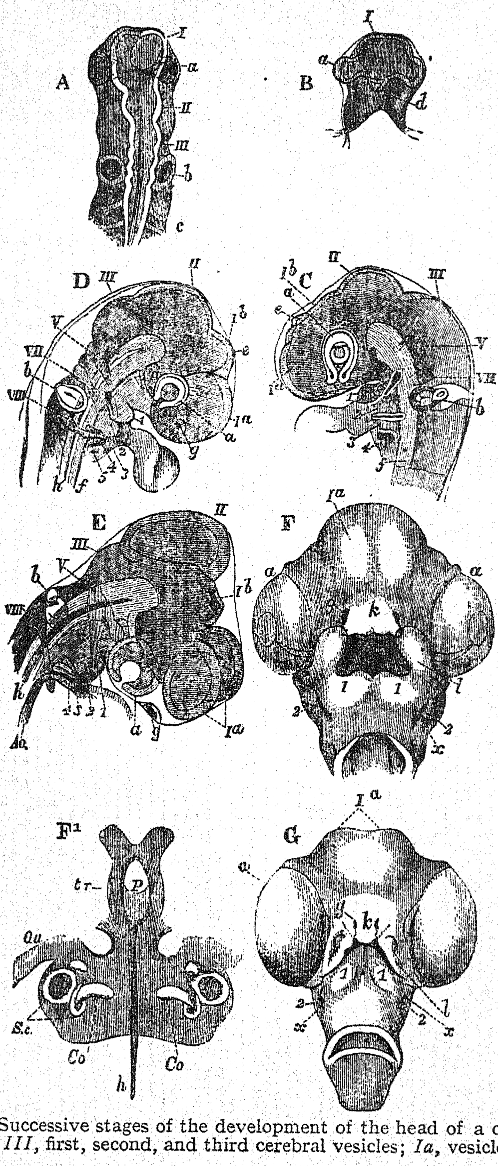


Fig. 11.—Successive stages of the development of the head of a chick.—*I, II, III*, first, second, and third cerebral vesicles; *Ia*, vesicle of the

verified Huschke's and Remak's statement that it does so arise, that I entertain no doubt whatever of the fact.[1] The outer ends of the olfactory sacs remain open, but those of the ocular and auditory sacs rapidly close up, and shut off their contents from all direct communication with the exterior. The olfactory nerve is developed from the anterior division of the anterior cerebral vesicle. The optic nerve is primarily developed from the posterior division of that vesicle, its connection with the middle vesicle (which eventually gives rise to the *corpora quadrigemina*) being only secondary. The auditory nerve is developed in the blastoderm adjacent to the third cerebral vesicle, so that the three pairs of sense-capsules do not correspond with the three primary cerebral vesicles.

While these changes have been going on in the proper cranial portion of the embryo, the rudiments of the face have made their appearance under a very singular guise. As the homologues of the dorsal laminæ in the head have grown upwards to inclose the cephalic cavity, so, plates, which correspond with the visceral laminæ of the trunk, have grown downwards, to constitute the posterior walls of the buccal, pharyngeal, and cervical regions. These visceral plates, however, do not remain entire and undivided, as do those of the trunk, but grooves appear in them, directed transversely to the axis of the trunk, and, the grooves deepening, eventually become converted into slits—the *visceral clefts*—which open into the pharyngeal cavity, and bound corresponding *visceral arches*. The first slit is situated immediately below and in front of the auditory sac, and separates the first and second visceral arches—the anterior boundary of

cerebral hemispheres; *Ib*, vesicle of the third ventricle; *a*, rudiments of the eyes and optic nerves; *b*, of the ears; *g*, of the olfactory organs; *d*, the infundibulum; *e*, the pineal gland; *c*, proto-vertebræ; *h*, notochord; 1, 2, 3, 4, 5, visceral arches; *V*, *VII*, *VIII*, the trigeminal, portio dura, and eighth pair of cranial nerves; *k*, the fronto-nasal process; *l*, the maxillary process; *x*, the first visceral cleft.

A, B, upper and under views of the head of a chick at the end of the second day.

C, side view at the third day.

D, side view at seventy-five hours.

E, side view of the head of a chick at the fifth day, which has been subjected to slight pressure.

F, head of a chick at the sixth day, viewed from below.

F[1], the cartilaginous cranium of the same.

P, pituitary space; *tr*, trabeculæ; *Qu*, quadrate cartilage; *Sc*, semicircular canals; *Co*, cochlea.

G, head of a chick at the seventh day, from below.

[1] See also Kölliker's "Entwickelungs Geschichte," p. 300, *et seq.*

the former being determined by the edges of a depression of the integument which will eventually become the buccal cavity (Fig. 11, C). A third, fourth, and fifth visceral arch are developed in successive order behind the first and second (Fig. 11, D); but as they are of no great moment in reference to the human skull, our attention may be confined to the latter.

It is particularly worthy of notice that, from the moment at which it is discernible as a distinct part, the root of the first visceral arch passes into the rudimentary cranium below, and in front of, the forepart of the auditory sac, while the root of the second is attached below and behind that sac. We shall find that the parts developed within these arches retain the same position in the adult state; so that any hypothesis which involves the supposition of an extensive change of place of these parts in the course of development is, *ipso facto*, unworthy of consideration.

Both the first and second visceral arches are connected with that part of the cranium which lies behind the flexure; but the inflected portion of the cranium in front of the bend exhibits, on each side, running from the root of the first visceral arch beneath the eye to the nasal sac, a ridge or elevation, which is called the *maxillary process*, and might be regarded as a visceral arch of the anterior division of the skull, from the base of which it is developed (Fig. 11, F).

Lastly, the middle part of the floor of the anterior cerebral vesicle, between the nasal sacs, thickens and gives rise to a broad, flat median process, with an expanded extremity, the terminal contour of which is excavated and slightly produced at the angles—the *fronto-nasal process* (Fig. 11, F, *k*).

At first, the cranium and all its arches are membranous, or composed of mere indifferent tissue, with the exception of the axial notochord; but, very early, chondrification commences. The indifferent tissue surrounding the notochord (the "investing mass" of Rathke) (Fig. 11, C, D, *f*), is converted into cartilage, and the same histological change takes place in the walls of the auditory capsules, and around the foramen magnum; the cartilage stops in the middle line, behind the pituitary body, but sends two processes, one on each side of that body, into the floor of the anterior division of the skull (Fig. 11, F^1, *tr*). These processes, the *trabeculæ cranii*, of Rathke, unite in front, and the cartilage formed by their union ends in the fronto-nasal process. The roof of the skull, and the greater part of its side-walls, except in the region of the foramen magnum, are, at first,

entirely membranous. Chondrification next takes place in the visceral arches; a rod of that substance, which coalesces with its fellow in the middle line, being formed in the axis of the several arches on each side.

Purposing to return to the visceral arches by and by, I shall now trace out the modifications which are undergone by the chondro-membranous brain-case. In the occipital region, and about the auditory capsules, which early attain a very large proportional size, the cartilage extends for some distance upon the infero-lateral parietes of the skull; on the floor of the posterior division of the skull it thickens notably, and forms a sort of model of the future basi-occipital and basi-sphenoidal regions, the interspace between the trabeculæ becoming rapidly obliterated and converted into the floor of the pituitary fossa. In front, the coalesced trabeculæ become changed into a plate of cartilage, compressed from side to side, which occupies the middle of the gradually-narrowing fronto-nasal process, as the ethmo-vomerine, or internasal, cartilage.

From the sides of the basi-sphenoid cartilaginous plates are developed, which foreshadow the form and relations of the alisphenoids; at the sides of the presphenoidal region of the cartilage, similar plates represent the orbito-sphenoids. In front of these the upper part of the internasal, or ethmoidal, cartilage passes laterally into broad deflected cartilaginous lamellæ, which curve round the olfactory sacs, and occupy the places of the lateral masses of the ethmoid and the inferior turbinal bones.

Thus far the terms of my description are almost as applicable to the embryonic cranium of Man as to that of the chick.

The human cranium has been observed forming part of an open groove; it undergoes a flexure, and develops visceral arches altogether similar to those of the chick, nor is there any reason to doubt that the organs of sense are developed in the same manner. The very earliest condition of the cartilaginous cranium of the human embryo has not been observed; but, at the beginning of the second month, it consists wholly of cartilage and of membrane, disposed in a manner which differs only in detail from that seen in the chick. Thus the occipital foramen is surrounded by cartilage, continuous with that which extends through the basi-sphenoidal, presphenoidal, and ethmoidal regions to the anterior end of the face. The alisphenoids and orbito-sphenoids are represented by cartilage, and cartilaginous

plates arch down from the summit of the internasal cartilage, on each side, to form the substratum on which the nasal bones, and in which the spongy bones, will be developed. That part of the cranial cartilage which lodges the auditory organ is

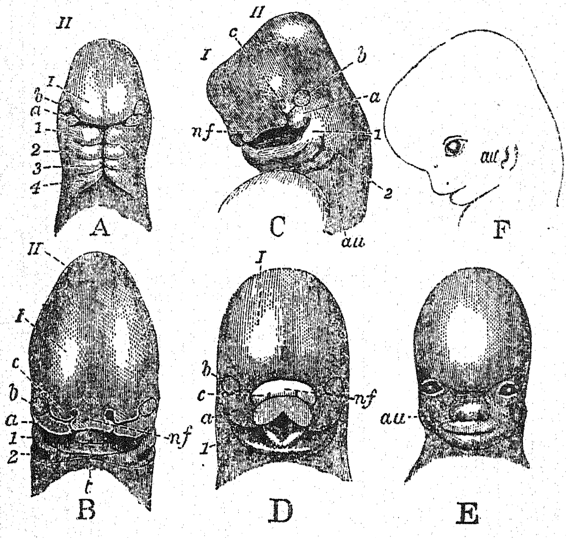


Fig. 12.—Successive embryonic conditions of the human head (after Ecker).—*I*, *II*, the first and second cerebral vesicles. 1, 2, 3, 4, the visceral arches; *a*, the maxillary process; *b*, the eye; *nf*, the middle naso-frontal process; *c*, the lateral naso-frontal process; *t*, the tongue; *au*, the outer part of the first visceral cleft, which eventually gives rise to the external auditory meatus.

A, at three weeks.
B, at five weeks.
C, at six weeks.
D, at seven weeks.
E, at eight weeks.
F, outline side view of E.

exceedingly large, and constitutes, not only an oval capsule for the membranous labyrinth, but sends back a continuation which fills the space corresponding to the *pars mastoidea*, and extends somewhat higher than it beneath the parietal region of the skull. All the upper part of the cranium is and remains simply membranous.

The relations of the regions of the chondro-cranium thus formed to the parts of the brain and to the exits of the nerves are the same as those which are observed in the bones which they prefigure.

When these bones begin to be developed, some of them make their appearance in the cartilage of the embryonic skull, some in the perichondrium, others in the membranous roof which is continuous with the perichondrium.

A single ossification appears around the notochord in the

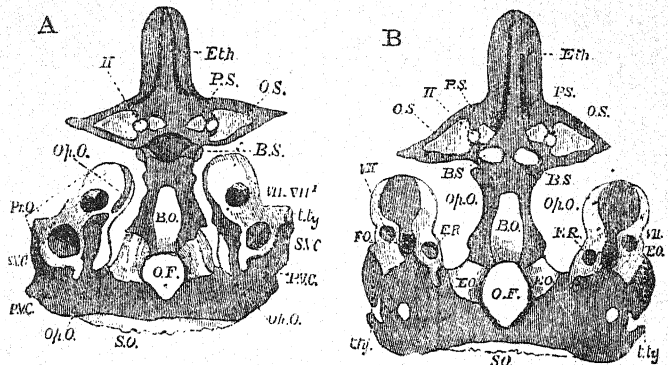


Fig. 13.—A, upper, and B, under view of the basis cranii and periotic cartilage of a human fœtus eight inches long. The alisphenoidal and immediately adjacent parts of the basi-sphenoid are omitted. The cartilage is darkly shaded, while the osseous deposits are left white, or but lightly shaded. The greater part of the supra-occipital is cut away. The clear spaces close to the dotted lines leading from *t.ty* are apertures in the cartilage. The epiotic classification has not yet appeared, and the pro-otic and opisthotic ossifications are quite distinct on the right side.

basi-occipital region, and lays the foundation for the basi-occipital bone. The ex-occipitals commence as single centres of ossification in the cartilage bounding the sides of the foramen magnum. The supra-occipital (*SO*) is developed from two ossifications in the cartilage above the foramen magnum, and from two others which appear, not in cartilage, but in the membranous roof of the skull above the limits of the cartilage, and so give rise to that part of the squama occipitis marked *SO*[1].

The basi-sphenoid is developed from two centres of ossification which appear in the floor of the *sella turcica*, but speedily

coalesce into one. Two separate centres of ossification appear in the cartilage between these and the alisphenoids, and form the *lingulæ sphenoidales*. Each alisphenoid is developed from a single centre in its cartilaginous predecessor, but the parietals are the result, not of the ossification of cartilage, but of that of the membrane which roofs in the skull. Each has its own centre of ossification in this membrane.

The presphenoid arises by two separate centres of ossification, one on the inner side of each optic foramen. (Fig. 13, *P.S.*) These centres coalesce with the orbito-sphenoids of their own side before they unite with one another.[1] The osseous orbito-

[1] The mode of ossification of the sphenoid bone is one of the most difficult questions in osteogenesis. Meckel has worked out the problem at great length in his "Archiv," Bd. i., and thus sums up his results in the "Handbuch der Menschlichen Anatomie," Bd. ii., pp. 102-4:—

"In the third month, the first osseous nuclei appear in the two great wings, and soon afterwards the internal pterygoid processes begin to ossify as separate bones. Next, a third pair of ossifications appears in the external circumference of the alæ minores; and then, about the fourth month, a seventh and eighth nucleus, which lie side by side in the body of the sphenoid. In the fifth month is formed, alongside this fourth pair, a fifth, between it and the great wings. Upon this the two median nuclei of the body coalesce. Soon arises a sixth nucleus, on the inner side of the optic foramen, and then a seventh appears between this and the fourth, so that, about the beginning of the seventh month, the sphenoid consists of thirteen separate bony nuclei, since, notwithstanding seven pairs have arisen, the two primary nuclei of the body early coalesced into one.

"From this time forth the number of the nuclei diminishes still more considerably by coalescence. Those nuclei coalesce earliest which give rise to the portions of the sphenoid, which persist in a separate state longest. The fourth, fifth, and seventh pair soon unite into one piece; the first and second, coalescing on each side, constitute two other pieces; the third and sixth two others; whereby, in the eighth month, the sphenoid consists of five pieces—the two greater wings, the lesser wings, and the body. Somewhat later the two lesser wings coalesce into one, and the sphenoid now consists of four pieces; thereupon the body and the anterior pieces unite, so that in the fully-formed fœtus the sphenoid consists of three pieces, the greater wings and internal pterygoid processes being still distinct; but in the first month after birth these three pieces unite into one."

The fifth pair of ossifications here mentioned are the *lingulæ*; the sixth, those which give rise to the presphenoid. Meckel's seventh pair of ossifications, which arise between the fourth (basi-sphenoidal) and the sixth (presphenoidal), and are said, in the "Archiv," to coalesce first with one another, and then with the basi-sphenoid, appear not to have been observed by other anatomists. I have not seen them, and they are not mentioned by Virchow, the latest writer on the subject. Virchow writes ("Entwickelung des Schädel-grundes," 1857):—"The posterior sphenoid arises (if we leave out of consideration the internal pterygoid processes which are developed as separate and independent bones), according to most authors, from three nuclei, but, according to my observations, from six. Two of these belong to the alæ magnæ (alæ temporales), or lateral arches (Bogenstücken) of the parietal vertebra. They arise in the third month, and the external pterygoids are produced by direct outgrowths from them. In

sphenoids arise each by one centre in the corresponding cartilages. The frontals, on the other hand, are developed, like the parietals, each from one centre in the membranous roof of the skull.

Thus we arrive at the singular result that, while all the bones of the basi-cranial axis, and all the lateral bones of the three

the third month, I also find two other centres of ossification which belong to the apices of the *lingulæ*, and are separated by distinct layers of cartilage from the others. The ossification of the *lingula* is almost complete in the fourth month, and its size is out of all relation to the dimensions of the other parts. It is a thick, obtusely-cylindrical process, which coalesces primarily with the body, and has nothing to do with the alæ. The *lingula* is therefore similar to an anterior or inferior transverse process (Parapophysis, Owen); and the *sulcus caroticus*, notwithstanding its position in the inner side of the *lingula*, resembles an open *foramen vertebrale*. However, Arnold's opinion that the Vidian canal answers to the canal for the vertebral artery, notwithstanding it is placed on the inner side of the lingula, deserves the careful attention of comparative anatomists. The ossification of the body begins in the third month, exactly under the pituitary fossa, which is already preformed in cartilage. Kerckring was the first to point out that here the adjacent osseous centres at first arise, and that they unite and form a biscuit-shaped mass in the fifth month. Once he saw this 'semilunula' even in the middle of the third month. Kölliker and I myself have met with it in fœtuses of three months. Other observers, as Nesbitt and Mayer, speak of a single centre in the third month, and in the fourth of two centres, which must be regarded as the result of the erroneous combination of different individual cases. I find constantly, in the beginning of the third month, two nuclei, which arise near the upper surface in the anterior wall of the pituitary fossa, and are separated by a broad layer of cartilage. Very soon, however, only a single osseous mass is present in the interior of the body, which extends through the whole thickness of the cartilage, while anteriorly and posteriorly it is still enveloped in cartilage. In a fœtus 19 centimètres [7½ inches] long, I saw the simple osseous nucleus in the bottom of the sella, as a transverse plate which had not yet united with the lingula."

"The anterior sphenoid is developed by the gradual coalescence of four osseous centres, of which again two belong to the body and one to each of the lesser wings. The latter are developed earlier than the former. They commence early in the third month, in the anterior clinoid processes, which are quite thick and osseous at a time when everything else in the anterior sphenoid is hyaline cartilage, and therefore are quite similar to the *lingulæ*. From this point ossification progresses rapidly, at last creeping round the circumference of the optic foramen to the body of the ala and to its anterior root. About the fifth month the lesser wing is completely solid in all parts. On the other hand, the nuclei in the body mostly appear somewhat later, usually in the fourth month, and at the inner edge of the optic foramen, so that they are at first separated by a tolerably broad median lamella of cartilage, which is continued into the ethmoid cartilage and *septum narium*. A union now very soon takes place between the centres of the body and those in the lesser wings, so that the optic foramen is surrounded by bone. . . . Later, at times, as it appears, as early as the fifth month, the two lateral masses unite into a larger central piece, which is free superiorly, while below and anteriorly, in the middle line, it is surrounded by broad masses of cartilage."—Virchow, *loc. cit.* pp. 15-18.

cranial arches, are primarily developed in cartilage, only one of the superior elements of these arches—the supra-occipital (*SO*)—is so; while the upper or "interparietal" portion of the *squama occipitis* (SO^1) and the two other pairs of superior elements of the arches are developed altogether from membrane.

The ethmoid is developed from a single centre, arising in the internasal cartilage. Its so-called lateral masses, with the two upper spongy bones, are likewise developed each from a single centre within the superior part of the inflected lateral cartilages which wall in the olfactory sacs. The inferior turbinals are ossifications of the lower parts of these cartilages. But the nasal bones are developed within the perichondrium, which is

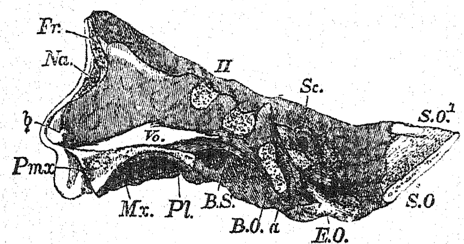


Fig. 14—Longitudinal and vertical section of the *basis cranii* of a fœtus somewhat older than the foregoing (Fig. 13). The basi-sphenoidal and presphenoidal centres have coalesced; but they and the basi-occipital are severally separated by wide interstices of cartilage, of which the whole ethmoidal region is still constituted.

continuous with the membrane in which the frontal bones are developed, and the vomer is produced within the perichondrium on the under-surface of the internasal septum. The bones of Bertin are also said to be developed from membrane—the perichondrium of the presphenoidal cartilage, or the walls of the olfactory sacs.

The development of the temporal bone is particularly worthy of attentive consideration. The squamosal and the tympanic elements are developed in membrane, and, at first, lie perfectly loose in this membrane, upon the outer side of the periotic cartilage. The tympanic is a delicate ring, open above; the squamosal is a mere rod, the *zygoma*, with an expanded posterior end, the *squama temporis*. The periotic mass, the styloid element, and the auditory ossicles are all preformed in cartilage.

The manner in which the cartilaginous capsule, which has the form of the subsequent periotic bones and lodges the membranous labyrinth, becomes ossified, has been much misunderstood; and as it is a point of vital importance in comparing the skull of man with that of the lower *Vertebrata*, I shall enter into some detail regarding it, as a matter of fact and as a matter of anatomical history.

Nearly two hundred years ago, Kerckringius, in his excellent "Osteogenia Fœtuum" (1670), laid the foundation for a proper understanding of this process:—

"Quarto mense mirum visu, quàm citò et quanta perfectione os squamosum magnam partem factum sit osseum. Os petrosum jam rubicundâ cartilagine signavit cavitatis suæ formam organorum auditûs capacem, nihil tamen adhuc præ se fert osseum, præterquam unam in longitudinem protensum crassiusculam et inæqualem lineam, annulo seu circulo, antea nominato, subjectam, et paulo longiùs protensam. Os itaque temporum hoc mense tribus constat ossiculis; annulo scilicet, osse squamoso, et illo jam commemorato.

"Quinto mense os squamosum ita adauctum est ut os syncipitis ferè, os autem cuneiforme omnino attigerit. Ossis petrosi pars illa quæ processum mammillarem constituit, terna de novo acquisivit ossicula: unum pyriformâ, acutiore, sui parte squamoso annectitur; alterum, scutum ovale referens, magnitudine priori vix cedens, mediâ cartilagine ab eo separatur; uti et tertium ab utroque, quamvis hoc magnitudine neutri sit æquiparandum, vix aciculæ majoris caput adæquans; sunt autem eo situ et ordine collocata, quem tabula fœtûs v. mensium, usurpata oculis facilius ad mentem quàm verba transmittet." . . .

"Constat ergo os temporum hoc quinto mense sex distinctis ossiculis; osse videlicet squamoso, annulo, osse internam cavitatem efformante et tribus notabilibus quæ hoc mense exorta esse diximus."—*L. c.*, pp. 222, 223.

The explanation of the third figure in the thirty-fifth plate, referred to in this passage, runs thus:—"Tria in osse petroso ossicula ostendit, e, e, e. Tria petrosi ossis distincta ossicula."

"Sexto mense pyriforme et ovale scutiforme coaluerunt in unum, tertium nonnihil auctum est magnitudine."—*L. c.*, p. 224.

The third figure of the thirty-sixth plate exhibits the condition thus described, and the explanation is:—"Bina in osse petroso ossicula ostendit. *D*, ossis petrosi pars quæ jam ex duobus coaluit; *e*, tertium ossis petrosi ossiculum."

"Septimo mense jam tertium illud ossiculum duobus mense superiore inter se coalitis accessit. . . .

"Nihil ergo de mense octavo nonoque addendum, nisi quòd ne tum quidem fœtus ullum habeat processum mamillarem, et quod adhuc insigni cartilagine distet os petrosum ab occipitis et syncipitis ossibus."—*L. c.*, p. 224.

The temporal bone of a seven months' fœtus is represented in Plate xxxvii. Fig. 2, with the explanation:—"Quæ primo tria, deinde bina, fuerunt in petroso ossicula, jam in unum coaluisse, ostendit. C, ossis petrosi substantia, ex tribus jam sæpe dictis in unum coalita."

Cassebohm ("Tractatus quatuor de Aure Humana," 1734, pp. 19 and 45; "Tractatus Quintus," 1735, p. 15) discovered that the little linear ossification mentioned in the first extract from Kerckringius is developed in the immediate vicinity of the *fenestra rotunda*, eventually surrounds it, and extends upon the base of the *pars petrosa*. But the first definite light thrown upon the signification of Kerckringius' "Tria ossa" is in the following extract from Meckel's "Handbuch der Vergleichenden Anatomie" (1820. Bd. iv., p. 49), though Meckel does not take the trouble to refer to and explain the older observer's statements:—

"4. *Bony labyrinth.*—In investigating the formation of the bony labyrinth, the origin of the bony substance of the petrous bone is very carefully to be distinguished from that of the labyrinth itself. The former begins earlier than the latter, according to the ordinary type of ossification, by the development of a loose, soft, reticulated tissue in the previously existing homogeneous cartilage, and extends from before backwards.

"The first part to ossify, about the end of the third month, is the circumference of the *fenestra rotunda*, which is remarkable by reason of the analogy of the *fenestra rotunda* to the tympanic annulus. The ossification begins above, descends posteriorly, and, after a ring has been formed in this manner, extends forwards.

"At the same time arises a proper centre of ossification, completely separated from this, at the external end of the superior vertical canal.

"After this, a third little scale is produced, opposite about the middle of the internal vertical semicircular canal.

"At the same time ossification extends swiftly backwards and downwards from the first piece, so as to give rise to the floor of the labyrinth.

"The second piece increases in size still more rapidly, so that, soon, the whole vertical semicircular canal, with the exception of its lower concave surface, is ossified. Simultaneously ossification is continued from its inner end over the inner surface of the petrous bone, surrounds the internal auditory meatus, penetrates into it, and so forms the floor of the cochlea.

"The horizontal semicircular canal begins to ossify, on its outer side, in the fifth month, by elongation of the bone forming the upper vertical semicircular canal: this is continued backwards, from without and below, round the horizontal semicircular canal. At least, I could discover no proper osseous centre for this canal, and it seems merely to become inclosed by the increase of the first and second."

All this is accurate, but, unfortunately, Meckel goes on to say, at page 51 of the work cited, that "the osseous labyrinth is at first perfectly separate from the bony mass of the petrous bone which surrounds it, is developed earlier than it, and is provided with quite a smooth surface, though the two lie close together;" and that "the bony labyrinth arises independently of the osseous substance of the petrous bone."

How Meckel arrived at this conclusion I do not know; but it is certainly erroneous, and it has been the means of creating a great deal of unsound speculation as to the ossified labyrinth being a something distinct from the proper *pars petrosa*.

It is further singular that, in this passage, Meckel not only, as I have said above, makes no reference to Kerckringius, but that he does not attempt to refer the regions of the *pars petrosa* and *mastoidea* to their separate origins. This is the more remarkable as, in his well-known paper on the "Ossification of the Vertebral and Cranial Bones" (Meckel's "Archiv," 1815), p. 636, he states expressly that the mastoid process arises from a special centre. Possibly the omission arose from Meckel's supposing that the exterior of the periotic mass is developed distinctly from the proper bony labyrinth.

Hallmann, in his well-known work, "Die Vergleichende Osteologie des Schläfenbeins" (1837), does not cite the account given by Meckel, and does not really improve upon the views of Kerckringius.

"In man, after, in the first place, the squamosal and then the *annulus tympanicus* are formed, the *os petrosum* and *mastoideum* is still a common cartilage, which fills, externally, the gap between the squamosal, the parietal, the supra-occipital and the

ex-occipital. When, in the fourth month, the cochlea and a part of the semicircular canals, viz., the upper canal and the anterior crus of the external canal, already consist of porous bony substance, while the ossification of the posterior canal (and probably of the posterior crus of the external canal) has not proceeded so far; the *pars mastoidea* appears as a single or double nodule of the size of a millet-seed, which is deposited upon the arch of the posterior canal, contributes to its ossification, and now soon spreads over the whole cartilage, the four neighbouring bones growing towards it. In Nos. 2543 and 9420 of the Berlin Museum, the insertion of this nodule upon the petrous bone is quite distinct. This osseous centre appears in the dry skeleton as an oval nodule, which I could easily scratch off without injuring the canals, which proves that it arises as a separate part."

Lastly, Kölliker, in his recently published "Entwickelungs Geschichte" (1861), sums up the present state of our knowledge respecting the ossification of the periotic cartilage as follows (p. 320):—

"The ossification of the labyrinth does not appear to have been investigated since the time of Cassebohm ('Tract. de Aure Hum.,' Hal. et Magdeb., 1734 and 1735) and J. Fr. Meckel ('Handb. d'Anat.' iv. p. 42, *et seq.*), which seems to be the reason why certain incorrect statements are repeated year after year in almost all handbooks. It is not the case that the external part of the pyramid of the petrosal bone and the labyrinth ossify separately, nor is it true that ossification begins as a thin crust on the wall of the labyrinth; on the contrary, ossification commences in the whole thickness of the wall of the labyrinth; in such a manner, however, that it appears externally sooner than internally, and the whole pyramid becomes ossified from centres which make their appearance first upon the cartilaginous semicircular canals and the cochlea. The number of these is, as has been rightly stated, three—one on the first turn of the cochlea, and one on each of the upper and posterior semicircular canals, whence, by degrees, the whole *pars petrosa*, together with the cartilaginous *pars mastoidea*, which is united with it, ossifies in a manner, the details of which would not especially interest you. On the other hand, I do not agree in the statements that have been made as to the time at which this ossification arises. Neither in the third, nor in the fourth month, as is commonly stated, is there a trace of ossification;

in fact, I have found the entire pyramid cartilaginous in an embryo five inches long at the eighteenth week, or, in the middle of the fifth month. Only at the end of the fifth, and especially in the sixth month, do the osseous deposits commence, but these increase very rapidly. In the sixth month, however, one meets with nothing but a beautiful reticulated cartilage ossification, and, as yet, no indication of true bone, which only arises, in the later months, from the periosteum of the labyrinth and from the external periosteum, whilst, contemporaneously, the internal cartilage ossification is reabsorbed and is replaced by a vascular true bone, which, by degrees, becomes finely spongy. The *Modiolus* and *Lamina spiralis*, in the sixth month, are still quite membranous, and only ossify at the end of fœtal life, without ever having been cartilaginous."

There is no doubt that the statement of Meckel, confirmed by Kölliker, that the periotic cartilage ossifies from three centres, is perfectly correct; there is no doubt, further, as Meckel, followed less clearly by Hallmann, has affirmed, that one of these centres gives rise to the future mastoid process; but it is equally indubitable that Kerckringius' original statement is true, and may be readily verified in the dry skulls of fœtuses of the age he mentions. The beautiful series of human fœtuses presented by Mr. MacMurdo, in the Museum of the Royal College of Surgeons, enable one easily to reconcile the teachings of the older and the later observers, when taken in conjunction with the study of the same parts in wet preparations.

Fig. 15, A, represents the periotic capsule of a human fœtus five and a quarter inches long.

One ossification in the cartilage (*Op.O.*) is seen surrounding the *fenestra rotunda* (*F.R.*), and extending a little way upon the promontory. A second, very small, quadrate ossification (*Pr.O.*) is situated at the outer end of the superior vertical semicircular canal, and apparently extends into the cartilaginous *tegmen tympani*. There is no other ossification in the cartilage than these two. As the upper part of the periotic mass in man answers to the front part, and as the lower part corresponds to the hind part of the same mass in the majority of the *Vertebrata*, I term the ossification on the superior vertical semicircular canal the *pro-otic* bone, that on the cochlea the *opisthotic* bone.

In some dry fœtal skulls of this age the opisthotic ossification only is seen, just as it is described by Kerckringius,

who seems not to have observed the pro-otic ossification at this period.

The pro-otic ossification rapidly extends, as Meckel states, over the superior vertical semicircular canal (see Fig. 13, A, p. 149), and reaching its posterior end, it includes the front and upper part of the posterior vertical canal; while, from the outer end of the anterior vertical canal, or the primitive centre, a mass of bone extends backwards in the periotic cartilage and, in the dry skull, appears conspicuously immediately behind the edge of the squamosal. (*Pr.O.*, Fig. 15, B.) This part of it is, in fact, that one of the "tria ossicula" of which Kerckringius says, "pyriformâ, acutiore sui parte, squamoso annectitur."

The opisthotic ossification likewise extends backwards and, its hinder extremity becoming apparent in the dry skull behind the tympanic, is Kerckringius' ossicle, "vix aciculæ majoris caput adæquans." (Fig. 15, B, *Op.O.*)

Lastly, the third ossicle, "scutum ovale referens," is that developed upon the posterior part of the posterior vertical semicircular canal, which gives rise to the mastoid process. (Fig. 15, B, *Ep.O.*)

Thus, in a fœtus between the fifth and sixth months, the "*pars mastoidea*" exhibits the appearance represented in Fig. 15, B. Its upper part is cartilaginous, but its lower part is occupied by the three "*ossicula*" of Kerckringius, which have now come into contact, and begun to unite, though their primitive contours are perfectly distinct.

The "*pars mastoidea*" of human anatomy is therefore not a single bone, but one, the "*scutum ovale*," combined with parts of two others; and as the "*scutum ovale*" is certainly the homologue of the bone I have termed *Epiotic* in the oviparous *Vertebrata*,[1] I propose to get rid of the confusing term "mastoid" altogether, and to call the specially "mastoid" part of the *pars mastoidea*, *Epiotic*.

Of the three periotic bones thus developed, the pro-otic gives rise to most of the *pars petrosa*, which is visible in the interior of the skull (Fig. 13, A), investing, as it does, the roof of the cochlea, the superior, and part of the posterior, vertical semicircular canals, the internal auditory meatus, and forming the

[1] Croonian Lecture. *Proceedings of the Royal Society*, 1858. In the absence of a sufficient knowledge of the development of the human temporal bone, I followed Hallmann in identifying the opisthotic of oviparous vertebrates with the mastoid of Mammals at the time this lecture was delivered.

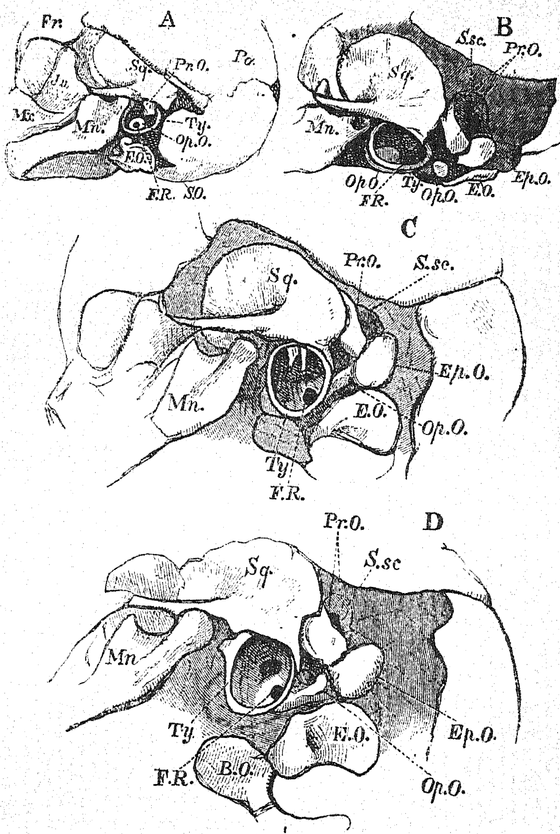


Fig. 15.—Development of the temporal bone.

A, from a fœtus $5\frac{1}{4}$ inches long, showing the commencing pro-otic and opisthotic ossification.

B, from a fœtus $8\frac{1}{2}$ inches long. The ossification in the *tegmen tympani* is no longer visible from without, but its continuation backwards over the superior, and part of the posterior, vertical semicircular canal is visible behind the squamosal. The epiotic ossification has made its appearance, and the hinder extremity of the opisthotic ossification appears behind the tympanic as the "third ossicle" of Kerckringius.

C, from a fœtus $10\frac{1}{4}$ inches long, the "tria ossicula" beginning to unite into the *pars mastoidea*.

D, from a fœtus $10\frac{1}{2}$ inches long, the tria ossicula anchylosed.

F.R., *foramen rotundum*.

S.sc, superior semicircular canal.

tegmen tympani. To it, in addition, is due the upper half of the circumference of the *fenestra ovalis,* and a considerable portion of the *pars mastoidea,* as has been stated above.

The opisthotic bone constitutes all the *pars petrosa* visible on the base of the skull, furnishes the floor of the cochlea, surrounds the *fenestra rotunda,* and contributes half the contour of the *fenestra ovalis;* gives rise to the carotid canal by developing a lamella of bone, which gradually wraps itself round the carotid, and so converts the primitive groove for the vessel into a complete tube, at the same time furnishing the inner part of its floor to the tympanum.

The lower edge of the squamosal is at first nearly straight, but it soon sends a curved process downwards behind the auditory meatus and between the tympanic ring and the periotic bones. In the fœtal skull represented in Fig. 15, D, it is obvious that this process corresponds with the *Margo tympanicus* or post-auditory process of the adult temporal bone; and the manner in which the hinder end of the pro-otic ossification is fitted in between it and the representative of the ascending part of the posterior root of the zygoma is very well shown.

The tympanic bone is at first a delicate ring, interrupted above, and with tapering ends, which approach one another very closely. The anterior end is thicker than the posterior, however, exhibiting a sort of flange, or internal process, which corresponds in position with the middle root of the zygoma, and eventually unites with it. The lower arched part of the tympanic ring becomes anchylosed with the floor of the tympanum, while its posterior and upper end unites with the squamosal.

In the process of ossification thus commenced and advancing in the fœtal cranium, certain centres, at first distinct, unite, and become hard to distinguish from one another even before birth.

At this period a considerable interval of cartilage separates the basi-occipital from the basi-sphenoid; but the latter has, as at *a,* Fig. 16, A, become firmly united with the presphenoid, though traces of the original separation, and remains of the primitive cartilage, are readily discernible.

The ex-occipitals are still distinct from the supra- and basi-occipital, and the alisphenoids are only suturally united with the *lingulæ sphenoidales,* which are still large in comparison with the basi-sphenoid, though they very early unite with it. The orbito-sphenoid and the presphenoid are completely anchy-

losed together by the superior root of the former, but the inferior root of the orbito-sphenoid, or middle clinoid process, abuts against the basi-sphenoid. (Fig. 17.)

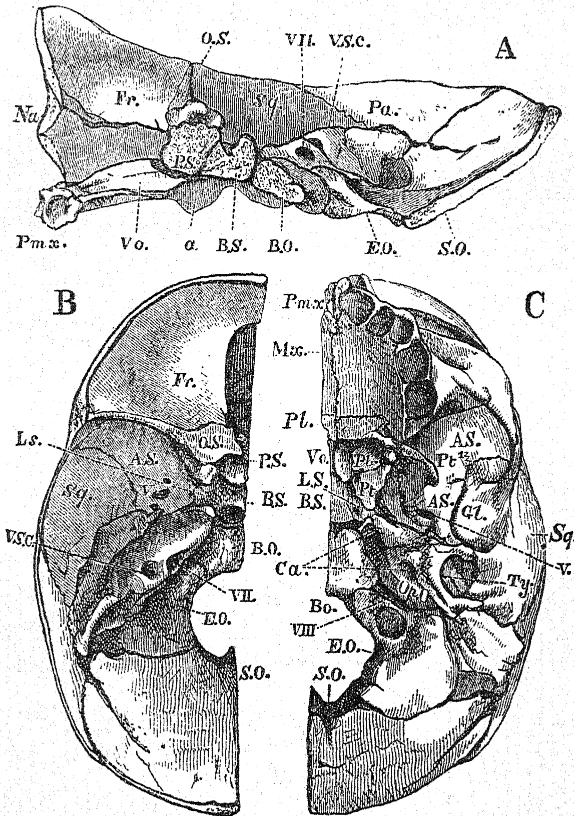


Fig. 16.—The human cranium at birth.—A, vertical and longitudinal section of the basal half of the cranium; B, upper, and C, under, view of the same preparation.

In the temporal bone—the pro-otic, opisthotic, and epiotic are indistinguishably united into the *pars petrosa* and *pars mastoidea*. The latter and the squamosal are firmly united,

but the petro-squamosal suture between the *tegmen tympani* of the former and the squamosal bone is obvious. The tympanic bone, still little more than a mere ring, is firmly anchylosed with the squamosal and with the opisthotic portion of the *pars petrosa*, but the indication of the primitive distinctness of the two latter can be readily traced. (Fig. 16, C.)

It is only after birth, and with the gradual advance towards adult years, that the spheno-occipital and the spheno-ethmoid synchondroses are obliterated, and the vomer becoming anchylosed with the ethmoid, the whole cranio-facial axis is fused into one bone, to which the ex-occipitals and supra-occipital, the alisphenoids and orbito-sphenoids, add themselves by a similar obliteration of the primitive separations. By addition

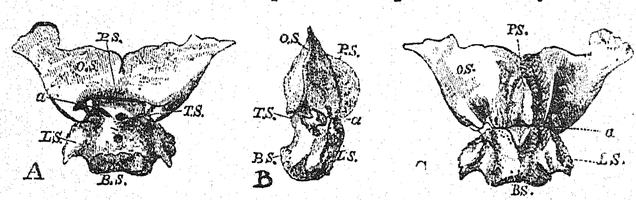


Fig. 17.—The basi-sphenoid and presphenoid, with the orbito-sphenoids of a human skull at birth.—A, viewed from above; B, from the right side; C, from below. *T.S.*, *tuberculum sellæ; L.S.*, *Lingula sphenoidalis* ; *a*, basi-presphenoidal synchondrosis.

of bony matter to its free margin, more especially to that of its lower part, the tympanic bone becomes converted into the gutter-like external auditory meatus. The epiotic grows out, inferiorly, into the mastoid process. The cavity beneath the bony arch in which the superior vertical semicircular canal is lodged, at first filled only by a plug of dura mater, becomes obliterated by bone.

The basi-sphenoid acquires larger dimensions in proportion to the *lingulæ sphenoidales*, and the posterior clinoid processes, at first cartilaginous, become completely ossified. The bones of Bertin unite with the under-surface of the presphenoid, and the latter becomes almost obliterated, or converted into a mere vertical lamina of bone, by the extension of the olfactory chambers backwards to give rise to the sphenoidal sinuses.

The lateral masses of the ethmoid become anchylosed with the *lamina perpendicularis*, and form one bone—the ethmoid of human anatomy.

Of the facial bones, the premaxilla is developed within that part of the naso-frontal process, which forms the anterior boundary of the mouth. The maxilla, the palatine, and pterygoid bones are produced within the maxillary process—the former from its external, the latter from its internal part. The internal pterygoid is, even before birth, united with the external pterygoid, the latter being simply an outgrowth downwards of the alisphenoid. None of these bones are at present known to be developed from cartilage, and the lachrymal and jugal are, similarly, membrane bones.

The cartilaginous rods within the first and second visceral arches undergo very remarkable changes. That of the first arch becomes modified into an upper portion, the future *incus*, and a lower portion, articulated with this, the future *malleus*, from which the rest of the cartilage is continued, as "Meckel's cartilage," along the inner side of the visceral arch (Fig. 18).

The incudal and malleal portions of the cartilage are, at first, proportionally very large, but their growth soon becomes arrested, and, a centre of ossification appearing in each, they become the *incus* and *malleus*. As the root of the first visceral arch is close to the outer and front part of the periotic capsule, so the *incus* and *malleus* have a corresponding position, and the tympanic bone, which is developed around the circumference of the modified first visceral cleft (which becomes converted into the auditory meatus, the tympanum, and the Eustachian tube), necessarily lies outside them, so that Meckel's cartilage passes between the tympanic bone and the periotic capsule, in its course from the malleus forwards and downwards. In front, the tympanic circlet marks the limit of its ossification. So far, it constitutes the *processus gracilis* (*Pg.*, Fig. 18), while, beyond this point, it eventually becomes obliterated. Very early, however, ossification takes place in the membrane of the first visceral arch, adjacent to the middle of the cartilage, and extending upwards towards the squamosal bone and, downwards and inwards, towards the symphysis, lays the foundation for each ramus of the lower jaw. The lower jaw, therefore, arises from membrane, and is not preformed in cartilage.

The axis of the second visceral arch becomes converted above into the *stapes*, below into the styloid cartilage, the stylohyoid ligament, and the lesser cornua of the hyoid bone, the body and greater cornua of which are developed from the

third visceral arch. Between the styloid cartilage and the *stapes* it is modified so as to form the stapedius muscle. A centre of ossification appears in the styloid cartilage, and, extending upwards and downwards, gives rise to the pyramid and the styloid process.

Some authors, however, give a somewhat different account of the metamorphoses of the cartilaginous axes of the first and second visceral arches to that which I have detailed, and which is based chiefly upon the researches of Meckel, Rathke, and

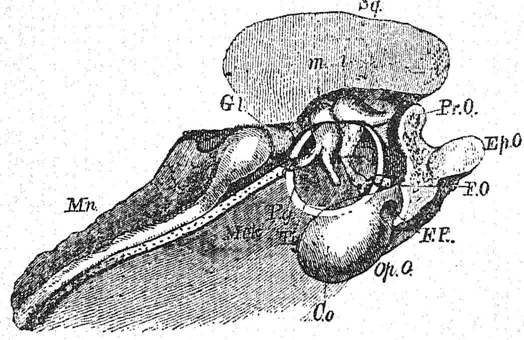


Fig. 18.—Part of the skull of a human fœtus at about the sixth month, dissected to show the auditory ossicles and Meckel's cartilage, *Mck*. *Gl*, the glenoid cavity. The *margo tympanicus* and adjacent parts of the squamosal are represented as if they were transparent, in order to show the position of the malleus (*m*) and incus (*i*). The tympanic bone (*Ty*) is merely indicated. *Co.*, the cochlea.

Reichert. Thus Gunther,[1] while he agrees with Reichert that the cartilaginous axis of the first visceral arch divides into three portions, the uppermost of which (that which is primitively connected with the skull) early disappears, while the middle and lower become converted respectively into the *incus* and the *malleus* with Meckel's cartilage, differs from him regarding the origin of the stapes. According to this writer:—"The middle division of the cartilaginous axis applies itself to the vesicular cartilaginous labyrinth, and when it comes into contact with the labyrinth, it sends out a small nodule, which

[1] Beobachtungen über die Entwickelung des Gehörorgans bei Menschen und höheren Säugethieren. 1842.

is received by a pit, the future *fenestra ovalis*." The nodule grows into a process, the lower part of which becoming bent on the upper, and eventually articulated, is converted into the stapes, while from the upper part originates the long process of the incus.

The auditory ossicles are at first altogether outside the tympanic cavity; and as the latter enlarges, its mucous membrane is reflected around the ossicles. The deposit of osseous matter for each ossicle commences in the perichondrium, and the stapes has three ossific centres, independently of that for the *os orbiculare*.

It can hardly be doubted that there is much yet to be learned respecting the first steps in the development of the *ossicula auditus*; but the investigation is one fraught with difficulties.[1]

III. THE SKULL OF THE PIKE COMPARED STRUCTURALLY AND DEVELOPMENTALLY WITH THAT OF MAN

In the series of animals possessing a bony skeleton, osseous fishes and man may be regarded as the extreme terms; and I now select the skull of an osseous fish—the Pike—for comparison with that of Man. Whatever community of structure obtains between these must be expected to persist throughout the intermediate terms; while the differences between them will be more or less completely bridged over by the subsequent study of the skulls of the lower Mammals, Birds, Reptiles, and Amphibians.

At first sight, the skull of a pike (Fig. 19) presents the most striking dissimilarity to that of a man. The skull proper is flattened, narrow, and elongated, its vertical height and transverse diameter being insignificant when compared with its antero-posterior length, the predominance of which is due chiefly to the disproportionate enlargement of the anterior half of the cranio-facial axis, *i.e.*, the presphenoidal and ethmo-vomerine regions. The brain-case is relatively very small and much depressed, instead of presenting the capacious dome of the human skull, while, on the other hand, the facial apparatus is

[1] See Magitot et Robin, "Cartilage de Meckel." *Ann. des Sc. Nat.* Sé. IVe. tome xviii.

very large and complex, and its components are almost all movable upon the skull. Another circumstance, which at once strikes the observer, is the fact that the lower jaw is not, as in Man, articulated directly with the skull; but is connected with the latter by the intermediation of a complex, mobile, suspensorial apparatus (Fig. 19, *H.M.* to *Qu.*), which articulates with the skull above and with the lower jaw below. A part of the same apparatus gives attachment to the hyoidean arch, and to the bones of the gill covers.

A certain fundamental resemblance may, however, be readily traced beneath these external differences. Thus, if a transverse and vertical section be taken through the pike's skull, so as to

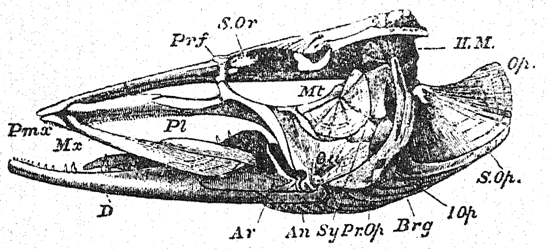


Fig. 19.—Side view of the skull of a Pike (after Agassiz).—*Prf*, prefrontal; *H.M.*, hyomandibular bone; *Op.*, operculum; *S.Op.*, sub-operculum; *I.Op*, inter-operculum; *Pr.Op*, pre-operculum; *Brg.*, branchiostegal rays; *Sy*, symplectic; *Mt*, meta-pterygoid; *Pl*, palato-pterygoid arch; *Qu.*, quadratum; *Ar*, articular; *An*, angular; *D*, dentary; *S.Or.*, supra-orbital bone.

traverse the organ of hearing, and to divide the suspensorium longitudinally into two parts, the posterior and anterior moieties of the skull will present the appearances represented in Figs. 20 and 21. The posterior segment (Fig. 20) is obviously comparable with the corresponding segment of the human skull (Fig. 3), consisting, as it does, of a floor, with an upper arch, which, in the recent state, inclosed part of the brain, and with a lower arch formed by the various parts of the hyoidean apparatus.

Furthermore, certain of the bones (*Ep.O*, *Op.O*, etc.) which enter into the composition of the upper arch are especially related, as in the corresponding section of the human skull, to the organ of hearing, and it is with some of these that the inferior arch is connected.

The anterior segment (Fig. 21) presents a similar general correspondence with the corresponding segment (Fig. 2) of the man's skull. That is to say, there is a floor with which is connected an upper arch, forming part of the brain-case, and a lower arch which enters into the composition of the face. The sides of this arch in the sectional view are partly constituted (compare Fig. 2) by bones specially connected with the auditory apparatus, and the peduncle of the lower arch is articulated

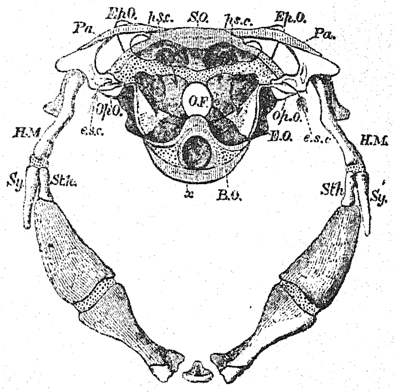


Fig. 20.—The posterior segment of the skull of a Pike which has been vertically and transversely bisected. The bones of the inferior arch are represented diagrammatically. The epiotic, opisthotic, pro-otic, and squamosal bones are left unshaded, as in the corresponding section of the human skull. *p.s.c.*, *e.s.c.*, arrows indicating the positions of the posterior and external semicircular canals; *x*, parasphenoid.

with these bones. The chamber contained within the lower arch, however, differs from that seen in the section of the human skull in that it is entirely devoted to the buccal cavity, and is not subdivided by processes of the palatine and maxillary bones into an upper, nasal, and a lower, oral, passage.

The comparison of the transverse sections of the Pike's with those of the Man's skull thus enables us to perceive certain resemblances between the two. In each there is an axis, upper and lower arches; in each the section separates the bones which lodge the auditory organs; and the most apparent difference between the two is the vastly greater proportionate size of the periotic bones in the Pike.

The comparison of the longitudinal section of the Man's skull with that of the Pike (Fig. 22) confirms the conclusions arrived at from the study of the transverse sections. A "cranio-facial axis," composed partly of bone and partly of cartilage, extends from the occipital foramen to the anterior extremity of the snout of the fish. The posterior part of this constitutes the floor of the cranial cavity, and is the basi-cranial axis. The anterior part, excluded from the cranial cavity, is, as in Man, the basi-facial axis.

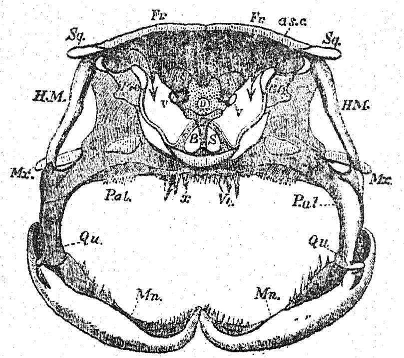


Fig. 21.—The anterior segment of the skull represented in Fig. 20.—*Mn*, mandible. *a.s.c.*, arrow indicating the position of the anterior semi-circular canal. The letters *B*, *S*, one on each side of the basi-sphenoid, are seen through the canal for the orbital muscles. The pro-otic bone is left unshaded. In this, and in the preceding figure, the dotted shading indicates cartilage; but, as the drawings were made from a dry skull, it must be remembered that the whole of the cartilage entering into the cranium is not represented.

Again, as in Man, three pair of chambers, destined for the lodgment of the organs of the higher senses, are placed symmetrically upon the sides of the Pike's skull. The olfactory chambers are situated just in front of *Prf.*, in Fig. 19, and the orbits beneath *S.Or.*, while the auditory organs are inclosed within the posterior bony walls of the brain-case, as indicated in the transverse sections. And, as in Man, the olfactory and auditory apparatuses are fixed within their chambers, while the eye is freely movable within the orbit.

Thus, for the Pike, I may repeat the phraseology which I employed in giving a general description of the skull of Man.

It consists of an axis, of upper and lower arches, and of chambers for the sensory organs.

The next point is to ascertain how far this correspondence, thus traced generally, extends into the details of the composition of the skull; and here we may conveniently begin, as before, with the study of the cranio-facial axis.

Viewed as a whole, this axis is rounded and thick behind, compressed from side to side in the median region, and thickened and depressed in front. It is composed, as I have said, partly of bone and partly of cartilage. Behind, it consists of a single well-ossified mass (*B.O.*), which offers, posteriorly, a deeply excavated conical articular facet, quite similar to that presented by the body of the first vertebra, with which it articulates. Anteriorly, it is also excavated in the middle, its conical cavity terminating the canal for the orbital muscles behind. Its upper face forms the hinder part of the floor of the cranial cavity and the inferior boundary of the occipital foramen. Its lower face is bevelled off in front, and articulates with the hinder part of the upper face of the bone *x*, Fig. 22.

Laterally and posteriorly, it articulates with the bones (*E.O.*), which constitute the lateral boundaries of the occipital foramen; while, laterally and anteriorly, its deeply-excavated surface is free, and forms part of the deep chamber in which the sacculus of the auditory organ is lodged. The greater part of this bone is solidly ossified throughout, but its conical anterior cavity is lined by a thin shell of bone, which is separated by a continuous layer of cartilage, thicker above than below, from the rest of the osseous mass.

In a longitudinal section (Fig. 22) of a fresh Pike's skull, the upper part of this layer of cartilage is readily seen, and can be traced without interruption, from the axis of the bone under description as far forwards as the posterior margin of the pituitary fossa, and therefore, for a long distance in front of the anterior termination of the bone *B.O.* The layer of cartilage bends down at the sides, and so enters into the lateral walls of the cavity for the orbital muscles. The cartilage, however, does not immediately constitute the floor of the skull, or the roof and side walls of the canal for the orbital muscles, seeing that it is coated over, on both its faces, by bony matter, which is continuous with that forming the inner and the outer faces of the bone *Pr.O.*

Although there can be no doubt, then, that the cartilaginous

lamella in question forms part of the basi-cranial axis, it does not, strictly speaking, form part of the floor of that skull, being shut out therefrom by the extension over it of the ossifications (*Pr.O.*), towards the middle line. Leaving these ossifications out of consideration, however, it may be said that the free edge of the middle part of the cartilaginous lamella forms the posterior boundary of the fossa for the pituitary body, which dips down, surrounded by membrane, through the centre of the canal for the orbital muscles, and rests upon the concave surface of an elevation of the bone *x* at *P*, Fig. 22. Immediately in front of this elevation cartilage reappears, and extends, as an inter-orbital, ethmoidal, and internasal septum, to the end of the snout. The cranial cavity rapidly narrows above the cartila-

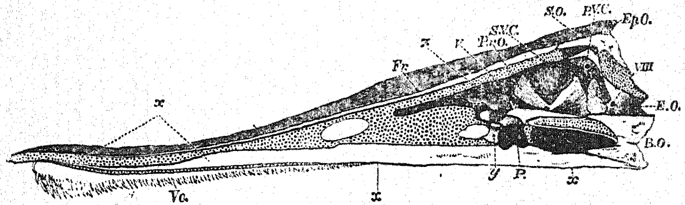


Fig. 22.—Longitudinal and vertical section of a fresh Pike's skull. The cut surface of cartilage is dotted. For *S.V.C.*, *P.V.C.*, read *a.s.c.*, *p.s.c.*, as in Figs. 20 and 21.

ginous inter-orbital septum, and ends where the olfactory lobes abut against the olfactory sacs. It appears to terminate much sooner, however; for the olfactory lobes, after running parallel with one another for some distance, diverge, and become separated by a plate of cartilage, which corresponds to a certain extent with the *crista galli* of the human skull.

Immediately in front of the pituitary fossa a thin plate-like ossification, *y*, is developed in the cartilage, and this plate sends off backwards and a little upwards, upon each side, a process which is connected posteriorly with the cranial floor. These two processes consequently lie at the sides of the pituitary fossa, and the "Y-shaped bone," as it has been well termed, thus furnishes part of the front and side walls of that fossa.

The next ossification to be noted in the cranio-facial axis of the Pike is the great bone *x* (Figs. 20 to 23), which stretches, like a splint, along the greater part of the length of the base of the skull.

The lower face of the hinder half of this bone is free, while that of its front half is covered by the bone, *Vo*. The upper face of its hinder half articulates, at first, with the lower surface of *B.O.*, but is then free for some distance, forming the floor of the canal for the orbital muscles, and articulates by expanded aliform processes of its sides with the lateral walls of that canal. At the front part of the canal it exhibits the elevation which forms the floor of the pituitary fossa, and then, depressed at the sides, but exhibiting a median superior ridge, it underlies the inter-orbital and ethmoidal cartilages.

The last ossification of the cranio-facial axis is a depressed

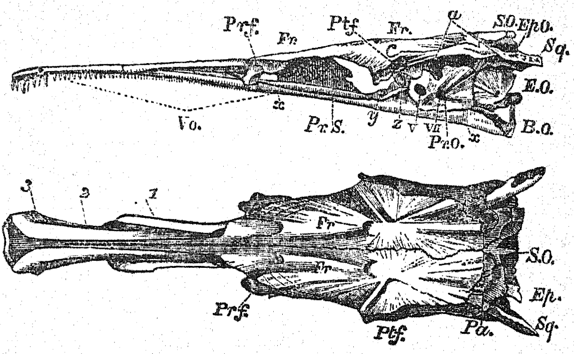


Fig. 23.—Side and upper views of a Pike's skull (after Agassiz).—*a*, the articular facet for the hyomandibular bone; *x*, the "*parasphenoid*;" *y*, the true basi-sphenoid; *z*, the alisphenoid.

bone *Vo*, thicker in front than behind, which fits on to the under-surface of the anterior half of the bone just described, and extends beyond it to the front end of the snout. The under-surface of this bone is free, enters into the middle of the roof of the palate, and bears teeth.

In comparing the cranio-facial axis of the Pike with that of Man, two pair of bones appear, at once, to correspond so closely that no reasonable doubt can be entertained as to their homology. These are the posterior and anterior bones of the series in each case. The former, in its relation to the spinal column, to the medulla oblongata, and to the lateral arches of the skull of the Pike, is precisely comparable with the basi-occipital of Man;

while the anterior bone as exactly answers to the vomer of man; except that the fish, being devoid of any communication between the olfactory chambers and the cavity of the mouth, the vomer has a different form, and has of course no relation to nasal passages.

Again, it seems obvious that the ethmoid is represented only by cartilage, as in the fœtal state of the human skull, for there is no ossification in that portion of the cranio-facial axis which lies between the olfactory sacs.

And the like appears to be true of the presphenoid, for all that vertical plate-like portion of the cranio-facial axis which lies between the orbits, and beneath the peduncles of the olfactory lobes, and in front of the crossing of the optic nerves, is merely cartilaginous.

The Y-shaped bone forms part of the front and side walls of the pituitary fossa, and its upper prolongations are connected behind with the bones *Pr.O*, and with the floor of the cranial cavity. In this floor, the long cartilaginous plate, already mentioned, constitutes the hinder boundary of the fossa, and separates the Y-shaped bone from the basi-occipital. Now, the proper basi-sphenoid (that is to say, the central ossification taken apart from the *lingulæ*) forms the front boundary of the pituitary fossa in Man, but extends obliquely downwards in front of it as the stem of the Y-shaped bone does in the Pike. Furthermore, in the fœtal human skull, the basi-sphenoid contributes nothing towards the posterior boundary of the pituitary fossa, which is formed by the long cartilaginous synchondrosis which connects the rudimentary basi-sphenoid with the basi-occipital. I identify the lamella of cartilage which I have described in the Pike with this synchondrosal portion of the fœtal human *basis cranii*.

But the basi-occipital, basi-sphenoid, presphenoid, ethmoid, and vomer of Man being now accounted for in the Pike's cranio-facial axis, what, it may be said, is the nature of the bone *x* to which the term "basi-sphenoid" is commonly applied?

It differs from any of the ossifications of the basi-sphenoidal cartilage in Man, not only by extending backwards beneath the basi-occipital, but by stretching forwards, beneath the presphenoidal and ethmoidal cartilages, to within a short distance of the anterior extremity of the cranium; and in the still more important circumstance that it is an ossification within the perichondrium, which can be stripped off, in skulls which have

been macerated, or steeped for a short time in boiling water, without injury to the cartilage upon which it is developed.

Mr. Parker has shown, in his valuable paper on *Balæniceps*,[1] that the so-called basi-sphenoid of birds is developed from three ossifications, a central one, the true basi-sphenoid, and two lateral and inferior centres—the "*basi-temporals*" (Parker), which appear to correspond with the *lingulæ* of Man.

The thought readily arises that the single bone *x* may corre-

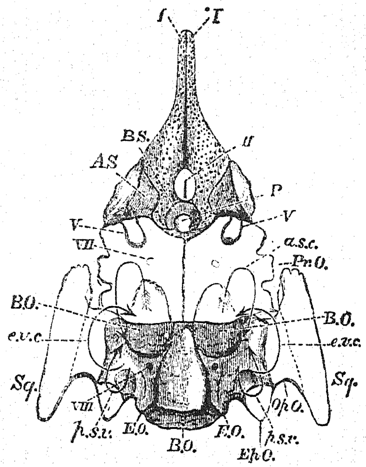


Fig. 24.—The basal and lateral bones of the skull of a Pike viewed from above. The squamosal and the three periotic bones are left unshaded. *P*, the pituitary fossa.

spond with these two basi-temporal ossifications. The latter, however, appear to be cartilage ossifications like the *lingulæ* themselves: and, upon the whole, I think it will be safer, at any rate for the present, to regard the bone *x* as peculiar to the branchiate *Vertebrata*, and to confer upon it the special name of "*parasphenoid*."

Connected with the bones of the basi-cranial axis are upper arches, and, as in Man, the hindermost of these arches consists of three elements, two of which are lateral and one superior. Each lateral bone articulates below with the basi-sphenoid, and

[1] Transactions of the Zoological Society, vol. iv.

forms the lateral boundary of the occipital foramen. Above, it unites with its fellow for a short distance, and so constitutes the upper boundary of that foramen, shutting out the superior bone from any share in its formation. Except in this point, it will be observed that the three bones quite correspond with the ex-occipitals and supra-occipital (*S.O.*) of Man. The ex-occipital (*E.O.*), however, further differs from that of Man in that it is perforated and not merely notched, by the foramen for the eighth pair, and that it is produced in front of, and external to, this foramen, so as to enter largely into the chamber which lodges the lower and posterior part of the organ of hearing. Furthermore, there is no perforation for any hypoglossal nerve, that nerve not being represented in a distinct form in the fish.

In the Pike, no bony wall separates the membranous labyrinth from the cavity of the skull, the periotic ossifications being all situated, as they are when they first appear in Man, upon the outer side of the capsule of the labyrinth; and this capsule is still less complete than that of the human fœtus, seeing that its inner wall is not even cartilaginous, but remains in the condition of membrane. Notwithstanding the comparatively incomplete condition of the periotic bones of the fish, however, they are as clearly and distinctly identifiable as any bones of the skull.

The large bone, *Pr.O.*, which occupies a great part of the wall of the cranial cavity, in front of the ex-occipital, has its front margin deeply notched for the exit of the third division of the trigeminal. It presents a foramen through which the *portio dura* passes; it protects the anterior part of the vestibule and the anterior vertical semicircular canal. In other words, it has exactly those relations to the auditory organ and to the cranial nerves which especially characterise the pro-otic ossification of Man—which, it will be recollected, also protects the anterior part of the organ of hearing, lies behind the exit of the third division of the trigeminal, and is perforated by the *portio dura.*

In minor respects, on the other hand, the pro-otic of the Pike differs from that of Man; as, for example, in its vast proportional size; in its remaining distinct from the other periotic bones; in the wide ossification which extends from it over the basal cartilage of the skull towards the middle line; and in coming into contact with the ex-occipital and basi-occipital behind. But none of these modifications really interfere with the homology of the bone—which we shall find to be identi-

fiable by the same essential characters throughout the vertebrate series.

The epiotic element is not less distinctly recognisable. The upper and lower crura of the great posterior vertical semicircular canal traverse notches in the supra-occipital and ex-occipital respectively, but the summit of the arch of the canal is inclosed within a distinct conical ossification, the "external occipital" of Cuvier. This ossification is, in fact, perched upon the posterior vertical semicircular canal, just as the human epiotic ossification is perched upon the summit of the arch of the same canal when it first appears; and if the semicircular canals of man were to grow in the same proportion to the brain-case as those of the fish, the epiotic would be carried out as far, and would leave a considerable space between the pro-otic and itself, into which the adjacent supra-occipital and ex-occipital bones might intrude, as they do in the fish.

The third of the periotic ossifications—the opisthotic—seems at first not to be discoverable in the Pike. But in some specimens of this fish, and in a great many other fishes, there is a distinct bone (which is particularly large and conspicuous in the *Gadidæ*) connected below and behind with the ex-occipital, in front with the pro-otic, internally and behind with the epiotic, and externally with the squamosal. It enters especially into the outer and posterior wall of the labyrinth, and protects a great part of the external semicircular canal, sharing this function with the pro-otic.

As there is neither *fenestra ovalis* nor *rotunda* in the fish, and as it is by no means certain whether the sacculus does or does not correspond with the cochlea of the higher *Vertebrata*, some of the best marks by which the opisthotic may be identified are wanting; but the relations of this bone to the other periotic ossifications seem to me to be decisive as to its real nature.

The periotic bones being thus identified, they are all eliminated from comparison with the proper supero-lateral constituents of the cranial arches. And there remains only one bone in the lateral walls of the Pike's cranial cavity which can answer to any of these, which is that marked *z* in Figure 22, *A.S.* in the other figures.

This bone has the form of a triangle, with its apex turned downwards. The hinder side of the triangle abuts against the anterior margin of the pro-otic, and closes the trigeminal notch in that bone anteriorly. The front margin ends in the cartila-

ginous side walls of the skull; the apex approaches, but stops a little short of, the lateral wing of the Y-shaped bone, or basisphenoid. The relations of this bone are therefore essentially those of the alisphenoid, though I think it quite possible that the orbito-sphenoid may, to a certain extent, be represented by its anterior portion.

The bones which enter into the roof of the skull (Fig. 23) remain for consideration. Of these, the supra-occipital, which has no additional constituent comparable to *S.O* in Man, has already been mentioned. It articulates in front with two very large and long bones (*Fr.*), separated by a median suture, which narrow in front of the orbits and end in a point beyond the nostrils, and but a short distance from the extremity of the snout. The supra-occipital lies between, and separates two other comparatively small and insignificant bones (*Pa.*), which are situated between the posterior edges of the parietals and the epiotics, and, strictly speaking, do not enter into the roof of the cranial cavity at all. Of these two pairs of bones, the anterior represent the frontals of Man, and the posterior his parietals. The position and proportions of the bones are, indeed, remarkably altered; but we shall find by and by that these very variable cranial elements undergo almost as great changes of proportion and relation even within the limits of the Mammalian class.

The three bones which correspond with the *pars petrosa* and *pars mastoidea* have already been identified. In Man another element, the squamosal, situated above and external to the pro-otic and opisthotic enters into the composition of the temporal bone. In the Pike there is a corresponding bone, which forms the external and posterior angle of the skull, and lies above and external to the pro-otic and opisthotic, being usually anchylosed with the latter. The under and outer surface of this squamosal bone contributes towards the formation of the articular facet for the suspensory apparatus of the lower jaw. There appears to be no ossification in the ethmoidal cartilage, which answers to the *lamina perpendicularis* of the ethmoid. But, separating the orbits from the nasal chambers, there is on each side of the frontals, and partially overlapped by them, a bone which helps to bound the hinder wall of the nasal chamber, which lies external to the olfactory nerve, and which is in immediate relation with the nasal division of the trigeminal nerve. This is the bone termed "pre-frontal" by Cuvier, and it obviously

corresponds with the lateral mass of the ethmoid in Man, which, in like manner, enters into the wall of the olfactory chamber, lies external to the olfactory nerves, and is traversed by the nasal division of the fifth.

Thus far the bones entering into the composition of the Pike's cranium (with the exception of the "parasphenoid") have been identified without much difficulty with those met with in Man. But there remain several others which seem to be without human homologues. These are, firstly, the bones called post-frontal, *Pt.f.*, which form the posterior, superior, and external angles of the orbits, and are wedged in between the alisphenoids and the pro-otics; secondly, the bones marked 1 and 2, developed upon the ethmoidal cartilage external to the points of the frontals. The pair 1,1, which immediately overhang the external nares, are probably to be regarded as the nasals of Man; but the nature of the second pair, 2,2, which lie internal to them, and extend to the end of the snout, is doubtful. Still less does there appear any reason to identify the bones 3,3, which are minute triangular ossifications in the substance of the cartilage between the bones 2,2 and the vomer, with any which exist in man. I consider them to be peculiar to the fish.

And now to sum up, in a few words, the structure of the brain-case of the Fish. We find, as in Man, a posterior, *occipital*, segment, consisting of basi-occipital, ex-occipital, and supra-occipital; a middle, *parietal*, segment, consisting, as in Man, of a basi-sphenoid, alisphenoids, and parietals, but in which the latter, in consequence of the disproportionate size of the frontals, are thrown far back out of connection with the alisphenoids; and, finally, an anterior, or, *frontal*, segment, of which only the frontals are separately distinguishable in the osseous state. The orbito-sphenoids and the presphenoid are alike represented only by cartilage and membrane, unless, indeed, as has been suggested, a part of the alisphenoid may take the place of the former bones.

Of the bony elements connected with the sense-capsules in Man, the pro-otic, opisthotic, and epiotic, together with the squamosal, have been clearly identified in the Pike; as have the pre-frontals and the vomer.

But certain bones present in Man have not been recognised in the Fish; while, on the other hand, certain bones present in the Fish appear to have no representatives in Man.

Thus, while the study of the cranial structure of the Man

and the Pike reveals a fundamental identity of composition between the two, it demonstrates the existence of a no less marked diversity, each type exhibiting structures and combinations peculiar to itself.

The principal bones which surround the oral cavity in the Pike are disposed, as in Man, in pairs, some being in front of and above the oral aperture, while others are behind and below that aperture; and they inclose the buccal and pharyngeal chambers.

The anterior pair of pre-oral bones (*Pmx.* Fig. 19), small, and

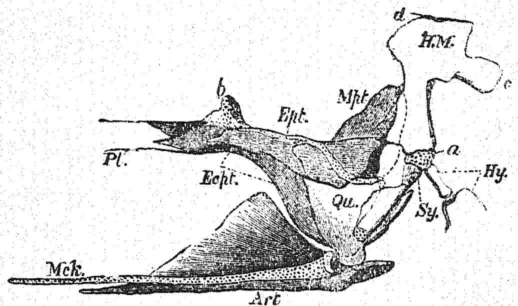


Fig. 25.—Palato-quadrate arch, with the hyomandibular and symplectic, the articular piece of the lower jaw, and Meckel's cartilage, of the Pike, seen from the inner side. *a*, the cartilage interposed between the hyomandibular and the symplectic; *b*, that which serves as a pedicle for the pterygo-palatine arch; *c*, process of the hyomandibular with which the operculum articulates; *d*, head of the hyomandibular which articulates with the side of the skull.

beset with teeth upon their under-surfaces, are connected with the vomer and the termination of the cartilaginous rostrum formed by the internasal septum. They obviously answer to the human pre-maxillæ. An elongated bone (*Mx.*), which bears no teeth, is connected anteriorly with the pre-maxilla, and, lying external to the other pre-oral bones, forms the boundary of the gape. Its homology with the maxilla of Man appears to be unquestionable. A second smaller bone is connected with the posterior part of the upper edge of the maxilla, and is usually regarded as a subdivision of it.

Behind the pre-maxillæ, and internal to the maxillæ, in the situation occupied by the palatine and pterygoid bones in Man,

the Pike has an osseous arch of much greater complexity and somewhat different connections.

The summit of this "palato-quadrate" arch is movably articulated, by a cartilaginous pedicle, with the outer surface of the pre-frontal process of the skull. The anterior crus of the arch stretches forwards, parallel with the vomer, to the pre-maxilla; its posterior crus extends backwards, and, spreading out, ends in an upper (*Mpt.*) and a lower (*Qu.*) prolongation.

Five bones enter into the composition of the arch—two median, two posterior, and one anterior. The median bones are so disposed that their anterior ends embrace the lower part of the cartilaginous pedicle (*b*), the one lying more external, and the other internal, to the latter. The more external has been called "*ectopterygoid*."[1] It exhibits a short, ascending process, running up towards the pre-frontal, and strengthening the cartilaginous pedicle; an anterior process which articulates with the bone *Pl.*; and a posterior arched prolongation, which descends in front of the bone *Qu.*, and articulates with its anterior edge. The internal bone, called "*entopterygoid*" (*Ept.*), is a nearly straight, flat bone, the anterior half of which is applied, like a splint, to the inner face of the ectopterygoid, while its broader posterior face is similarly adjusted, above, to the bone *Mpt.*, and, below, to the bone *Qu.* The two last-mentioned "posterior" bones of the arch are termed respectively the "*metapterygoid*" and the "*quadrate*" bones. The former is a broad, four-sided bone, convex upon its inner surface, which presents a raised, curved ridge, beneath which the entopterygoid is received anteriorly and the hyomandibular posteriorly. It is connected below with the quadrate bone, and, behind, it overlaps the hyomandibular (*H.M.*) and the symplectic (*Sy.*).

The os quadratum (*Qu.*), so termed, not on account of its form, which is triangular, but by reason of its identity with a bone called by the same name in Birds and Reptiles, presents inferiorly an articular head, with an elongated articular surface, convex from before backwards, for the lower jaw. On the posterior part of its inner surface it has a deep groove, directed from above downwards, very nearly parallel to its posterior edge. Into this the symplectic is received.

[1] Not to multiply names unnecessarily, I adopt this term, which involves no theoretical implications. It must be carefully born in mind, however, that this "ectopterygoid" has nothing to do with the "external pterygoid" process of Man.

The anterior bone (*Pa.*), lastly, is elongated and flattened, and bears teeth upon its lower surface. It is received anteriorly into the re-entering angle between the vomer and the pre-maxilla and maxilla. It is usually regarded as the palatine bone.

Before attempting to discuss the homologies of these several constituents of the palato-quadrate arch in the fish, it will be necessary to take into account the nature and arrangement of its post-oral facial bones.

In Man, the post-oral bones are arranged in two arches—the mandibular and the hyoidean; or, more strictly speaking, since the hyoidean arch is really composed of two, indicated by its lesser and greater cornua, there are three post-oral arches.

In the Pike, the lower jaw forms a mandibular arch, obviously corresponding in a general way with that of Man; behind this follows a second arch, answering to the styloid processes, stylo-hyoid ligaments, and cornua minora of the human hyoid, but with much greater masses of bone entering into its composition; and this is succeeded by no fewer than five other arches, the four anterior of which, supporting the gill filaments, are termed the "*branchial arches*," while the last pair, which carry no branchiæ, and are much smaller than the others, are called the "*inferior pharyngeal bones*."

The symphysis of the lower jaw is formed by the ligamentous union of two bones, which carry the inferior teeth of the Pike, and correspond respectively with the rami of the human mandible. But, besides these *dentary* bones (*D*, Fig. 19), each half of the lower jaw of the Pike has two other constituents, which are not represented in the human lower jaw. One of these is a small bone, which forms the lower part of the angular process of the jaw. It is termed the *os angulare*, or angular piece (*An*, Fig. 19). The other is a large triangular bone, which fits in between the dentary and the angular, and is termed the articular (*os articulare*, *Ar.*), because on its upper surface it bears a concave articular fossa, into which the condyle of the quadrate bone is received (Fig. 25). The cartilage which partially forms the walls of this fossa is continued into a long tapering rod, which lies upon the inner surface of the articular and of the dentary, and terminates in a point shortly before reaching the symphysis (*Mck.*, Fig. 25).

This rod of cartilage affords a safe basis upon which to found a homological argumentation. For it most certainly corresponds with Meckel's cartilage in the human fœtus, and the dentary

bone lies outside it, in just the same way as the dentigerous ramus of the human mandible lies outside Meckel's cartilage. But the articular bone is an ossification in and around the proximal end of Meckel's cartilage in the Pike, just as the *malleus* is an ossification in and around the proximal end of Meckel's cartilage in the human fœtus; and the *os quadratum* is related to the *os articulare* of the fish in the same way as the *incus* is related to the *malleus*.

Hence it is to be concluded, in the absence of any evidence to the contrary, that the articular piece of the Pike's lower jaw answers to the *malleus*, and the quadrate bone to the *incus*.

I am not aware that any evidence can be adduced against this view; but, on the other hand, the relations of the parts thus identified to the *portio dura* of the seventh nerve, in Man and in the Fish, seem to me to afford it much support.

The *portio dura* in the former perforates the *pars petrosa*, and, after skirting the inner wall of the tympanum, external to the labyrinth, leaves the skull by the stylo-mastoid foramen. Before it does so, however, it gives off a recurrent branch, the *chorda tympani*, which takes a very singular course—passing between the pyramid, which is the upper end of the hyoidean arch, and the tympanic bone, entering the tympanum, crossing the auditory ossicles to make its way out at the front wall of the tympanum, between the tympanic and the squamosal, then uniting with the gustatory division of the trigeminal, and passing down along the inner side of the ramus of the mandible with it, until eventually it leaves it to become connected with the sub-maxillary ganglion.

The principal portion of the *portio dura*, on the other hand, makes its way out by the stylo-mastoid foramen, and is distributed to the facial muscles, some comparatively insignificant branches only, being furnished to the levators of the hyoidean apparatus and depressors of the lower jaw. But, as has been already stated, the facial muscles, so important and largely developed in Man, become insignificant in the lower Vertebrates, and are not represented at all in the Fish. Hence, in the latter, we might expect to find only mandibular and hyoidean branches of the *portio dura* corresponding with the *chorda tympani* on the one hand, and the stylo-hyoidean and digastric branches, on the other, in Man. And this is really the case. For the *portio dura* of the Pike, which leaves the skull by a special foramen in the pro-otic bone, traverses the hyomandibular bone, and then

divides into two branches, one of which runs backwards to the hyoidean arch; while the other, directed forwards and downwards, passes to the inner side of the quadrate bone, and over its articulation with the *articulare* to the inner surface of the lower jaw, along which it runs to the extremity of the ramus. This last branch is obviously the representative of the *chorda tympani*, and its relations to the quadrate and articular bones are, it will be observed, very similar to those which the corresponding nerve has to the *incus* and *malleus* in Man.

Holding fast, then, by this determination of the homologies of the *articulare* and *quadratum*, what is the nature of the other bones entering into the palato-quadrate arch?

The *metapterygoid* may perhaps answer to the *os orbiculare*. The manner of its connection with the quadrate (*incus*) suggests this view, for which, however, I cannot pretend to offer any positive proof.

That the other three bones answer in a general way to the pterygo-palatine bones of Man is certain. The pterygoid of Man, it is true, is in no way connected with the incus, while both bones *Ecpt.* and *Ept.* are united with the quadratum. But this is in reality no difficulty, for we shall find that, in the higher oviparous *Vertebrata*, the *os quadratum* is very generally connected with a bone which is universally admitted to correspond with the pterygoid of Man.

Again, both the palatine and the pterygoid bones of Man are articulated with the base of the skull, while the palato-pterygoid arch of the Fish is not directly connected with any of the basi-cranial bones; but, in many of the higher *Vertebrata*, the pterygo-palatine arch is almost as free of the base of the skull as in the Fish.

No doubt, then, the palato-pterygoid bones of the Fish, taken together, answer to the palato-pterygoid bones of the Man; but it is a very difficult matter to identify the separate constituents of the two arches.

One of the most striking features of the palatine bone, not only in Man, but in the *Vertebrata* generally, is its articulation with the pre-frontal, or lateral mass of the ethmoid. If, guided by this character, we seek for the homologue of the palatine in the Fish, the so-called "ectopterygoid" alone satisfies the conditions. But if this bone be the homologue of the true palatine, the bone *Pl.* must be regarded as a dismemberment, or sub-

division of the palatine,[1] and the entopterygoid will take the place of the true pterygoid.

The palato-quadrate arch, with the lower jaw, is immediately suspended to the skull only by the articulation of the cartilaginous pedicle *b* (Fig. 25) with the pre-frontal, none of the posterior elements of the arch being directly articulated with the skull. They are indirectly united with the latter, however, by two very remarkable bones, the *Hyomandibular* (*H.M.*) and the *Symplectic* (*Sy.*).

The *os hyomandibulare* is a broad flattened bone, somewhat constricted in the middle, and divided below into an anterior and a posterior process. The upper convex edge of the bone (*d*, Fig. 25) fits into an elongated, concave, glenoidal fossa bounded by the squamosal, opisthotic, and pro-otic bones, and swings freely therein, in a plane perpendicular to the longitudinal axis of the skull. The large anterior inferior process articulates by its anterior edge and outer face with the metapterygoid, while below it is united by a persistent synchondrosis with the irregular styliform bone, the *Symplectic*, which is firmly fitted into the groove already described upon the inner face of the quadrate bone.

The connection thus established between the hyomandibular and the symplectic, is strengthened externally by the firm apposition of a curved elongated bone, the *Pre-operculum*, to the hyomandibular above and to the quadrate bone below.

The hyoidean arch consists of two median bones,—an anterior, the "*entoglossal*," which supports the tongue; and a posterior, the "*urohyal*." Its lateral cornua are formed by four bones, two small (*basi-hyal*), and two large (*epi* and *cerato-hyals*) on each side, the latter supporting the "branchiostegal rays" on which the branchiostegal membrane is spread out; and the upper of the two larger bones is connected with the synchondrosis between the hyomandibular and symplectic by a styliform bone—the *stylo-hyal* (Fig. 25, *Hy.*). Thus, the hyomandibular may be regarded as common to the mandibular and the hyoidean arches, supporting the former, indirectly, by means of the symplectic, and the latter directly, by means of the stylo-hyal.

The stylo-hyal very probably corresponds with the styloid

[1] Looking upon *Pa.* and *Ecpt.* as one bone homologous with the palatine of Man, it will be found that in osseous Fishes the separation between them takes place sometimes in front of the pre-frontal articulation, as in the Pike, sometimes behind it, as in the Cod and most bony fishes.

process and pyramid of Man, but it is difficult to find any very sure footing for our interpretations beyond this point.

The manner in which the symplectic is connected, on the one hand, with the representative of the *incus*, and, on the other hand, with that of the styloid process and pyramid, is strongly suggestive of a relation between this bone and the stapes. But it must no less be admitted that similar arguments might be used in favour of the stapedial character of the hyomandibular bone, the articulation of which with the pro-otic and opisthotic might be compared with the fitting in of the stapes into the *fenestra ovalis*, which is bounded by these two bones; or, again, plausible arguments might be brought forward in favour of the view that the hyomandibular, at any rate, is a bone special to fishes. At present, it may be well merely to indicate these various possibilities, as the study of development has hardly been carried sufficiently far to enable us to decide in favour of one rather than of another.

Each of the four anterior branchial arches is composed of four bones, and the branchial arches of opposite sides are united by connecting cartilages and median ossifications. The anterior or first arch, which corresponds with the greater cornu of the hyoid of Man, is fixed to the pro-otic bone, between the exits of the trigeminal and the *portio dura*, by cartilage. The succeeding arches have no osseous or cartilaginous representatives in Man. The branchiostegal rays attached to the epi-hyal and cerato-hyal are in like case.

Three bones, the *operculum* (*Op.*), *sub-operculum* (*S.Op.*), and *inter-operculum* (*I.Op.*), are developed within the membranous gill-cover, and serve to strengthen it (Fig. 19). The operculum is articulated with the posterior and inferior process of the hyomandibular bone; the inter-operculum is connected by ligament with the angular piece of the jaw, the sub-operculum lies between the two.

The gill-cover is developed from the outer surface of the second visceral arch, and corresponds with the concha of the ear in the human subject; and as the latter part contains no osseous elements, it is obviously in vain to seek for the homologues of these bones in Man.

The *pre-operculum*, which, as I have stated above, binds together the hyomandibular and the quadrate bone externally, has been compared with the tympanic bone of Man, and the position of the bone and its relations to the representatives of

the *ossicula auditûs* are certainly not altogether unfavourable to this view.

These are the most important bones in the Pike's skull, but several yet remain for consideration.

Thus there is a small, oval, *supra-orbital* ossicle (*S.Or.*, Fig.19) attached to the outer margin of the frontal, above the orbit, and an inverted arch of *sub-orbital* bones which bound the orbital cavity externally and inferiorly. The sub-orbital series consists of a large anterior bone, which lies beside the nasal, and of five or six smaller bones, the hindermost of which is connected with, or attached close to, the post-frontal.

Finally, in the Pike, a forked bone, the *supra-scapula*, suspends the scapular arch to the apices of the squamosal and epiotic bones. This bone, it need hardly be said, is without a distinct osseous representative in Man.

The merely anatomical comparison of the facial bones of the Pike with those of Man thus leads to a conclusion very similar to that attained by the examination of the bones of the skull proper. There is a certain identity of fundamental plan upon which special structural peculiarities are superadded in each case. Both types of skull exhibit many bones in common, but in each type, some of these bones acquire special arrangements and very different relative magnitudes; and each type exhibits bones peculiar to itself, the number of those present in the Fish and absent in the Man, being very much greater than of those present in the Man, and absent in the Fish. As might be expected, the study of the development of the Fish's cranium brings out into still stronger light the fundamental resemblances of its structure with that of the higher Vertebrates. The primitive groove makes its appearance on the blastoderm, and becomes converted into a canal by the arching over and coalescence of the dorsel laminæ. The anterior part of the canal dilates and becomes subdivided into cerebral vesicles. The notochord appears and terminates, in front, in a point behind the pituitary body; while round its apex, that bend of the primitive cranium takes place which constitutes the cephalic flexure. The organs of sense make their appearance in the same regions, and the visceral arches and clefts are developed in the same way. But a greater number of them appear, and the posterior ones, instead of vanishing, give rise to the branchial skeleton and branchial clefts. The mandible is developed in the first visceral arch, and

the hyoid apparatus in the second, as in Man; but the details of the mode of origin of the hyomandibular and symplectic, of the palatine and maxillary apparatus, and of the naso-frontal process, have not been as yet worked out with sufficient thorough-

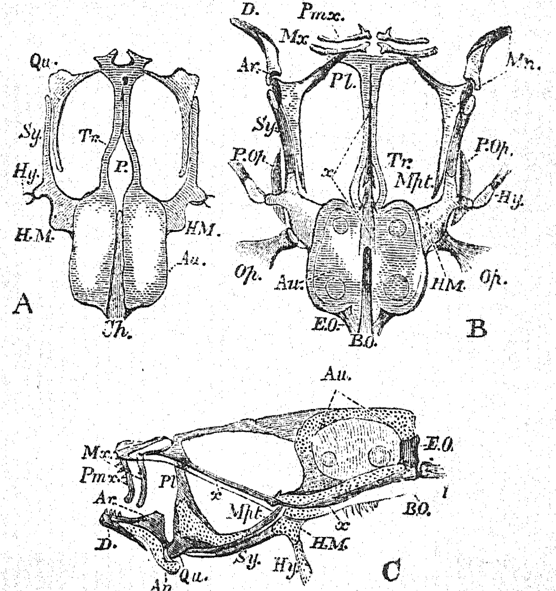


Fig. 26.—The cartilaginous and partially ossified crania of young Sticklebacks (*Gasterosteus*).—A, in a very early, B, in a more advanced condition, from above; C, viewed from the side; *Ch.*, notochord; *Au.*, auditory capsules; *P*, pituitary fossa; *Tr*, trabeculæ; *x*, parasphenoid; *H.M.*, *Sy.*, *Qu.*, indicate not only the bones, but the pre-existing cartilages.

ness to enable us to determine with certainty the homologies of all the resulting parts.

The cranium is at first wholly membranous, but after a time it becomes partially chondrified in the same way as in the higher Vertebrates (Fig. 26). Cartilage appears in the base of the skull upon each side of the notochord, and surrounds the great auditory capsules. Anteriorly it divides into two processes, the *trabeculæ cranii* (*Tr.*), which separate so as to inclose

the pituitary fossa (*P*), and reunite, in front of it, to form the ethmo-vomerine rostrum. From the floor of the skull, at the front and lateral part of each auditory capsule, a cartilaginous process (*HM.*) is given off, and passing downwards and forwards ends in a free styliform process, which lies parallel with, and is bound by connective tissue to, the free hinder crus of an inverted

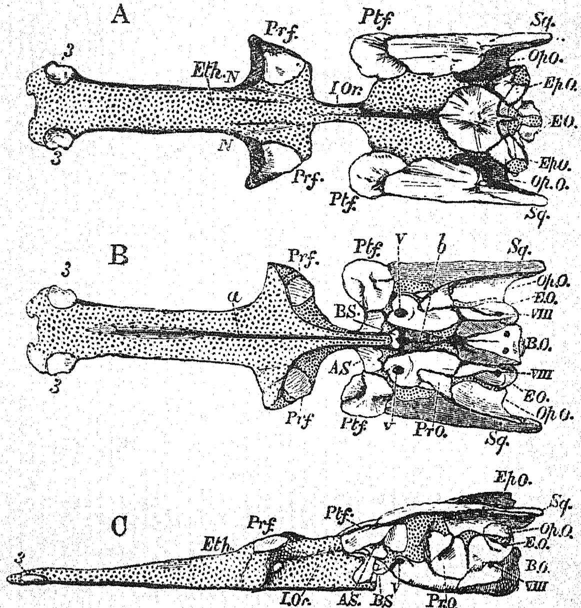


Fig. 27.—The cartilaginous cranium of a Pike, with its intrinsic ossifications viewed, A, from above; B, from below; C, from the left side. *N*, *N*, nasal fossæ; *I.Or*, inter-orbital septum; *a*, groove for a median ridge of the parasphenoid; *b*, canal for the orbital muscles.

arch of cartilage, the anterior crus of which passes into the prefrontal region of the ethmo-vomerine cartilage. The centre of this palato-quadrate arch is prolonged into a process (*Qu.*), which articulates with the cartilaginous ramus of the mandible, while the upper part of the cartilage (*HM. Sy.*) gives attachment to the cartilaginous hyoid (*Hy.*).

This is the earliest condition of the cartilaginous cranium of the osseous fish that has yet been observed; but it can hardly

be doubted that the hyomandibular and palato-quadrate cartilages have already deviated considerably from their primitive condition, and it would be a matter of great interest to ascertain whether these cartilages are primitively continuous; or whether, on the other hand, the hyomandibular altogether belongs to the second visceral arch, while the hinder crus of the palato-quadrate belongs to the first, but has become detached from its primitive connection with the *basis cranii.*

The basi-occipital originates as an ossification, which immediately surrounds and incloses the end of the notochord, and extends into the adjacent cartilage. The ex-occipital is developed within the substance of the cartilaginous cranium on each side of the basi-occipital. The parasphenoid, on the other hand, is developed as a superficial ossification in the perichondrium of the base of the skull, and extends in front of, and behind, the pituitary fossa in this membrane. The pre-maxillæ and maxillæ have no cartilaginous predecessors, nor have the dentary and angular pieces of the lower jaw. The palatine is developed around, if not in, the anterior crus of the palato-quadrate arch; the metapterygoid in the same relation to its posterior crus; the quadrate bone, in its inferior process. The symplectic is a cortical ossification of the styliform part of the hyomandibular cartilage, the ossification of the rest of the latter giving rise to the hyomandibular bone itself (Fig. 26).

In many osseous fishes, such as the Carp, the cartilaginous cranium disappears, with age, as completely as it does in Man; but, in the Pike, it not only persists, but grows and enlarges with age, so that the relations of the cranial bones to cartilage, or to membrane, can be investigated at any period of life.

If the skull of an adult Pike be macerated, or, better, steeped for a short time in boiling water, a number of the cranial bones will separate with great ease from a sort of model of the skull chiefly composed of cartilage.

This "cartilaginous skull" forms a complete roof over the cranial cavity (Fig. 27, A), whence it is continued, without interruption, to the anterior end of the cranium, forming the narrow inter-orbital septum (*I.Or.*) and the broad internasal rostrum (*Eth.*), and giving rise to two antorbital processes (*Prf.*), which separate the orbits from the nasal chambers, and are perforated by the olfactory nerve, and by the nasal division of the fifth.

The inter-orbital cartilage is interrupted by an oval space filled with membrane, just in front of the basi-sphenoid, so that

it is continued to the lower end of that bone only by a slender cartilaginous rod, which passes into the stem of the Y-shaped basi-sphenoid (Fig. 27, C).

The cartilaginous basis of the skull, therefore, is not continued back along the floor of the canal for the orbital muscles. The roof of the orbital canal contains cartilage in the middle line, which is almost completely hidden in front by the extension towards one another of the horizontal laminæ of the pro-otic bones. The under-surface of the inter-orbital septum and of the greater part of the cartilaginous rostrum is marked by a deep groove (*a*, Fig. 27, B), into which a median ridge of the para-sphenoid is received.

The bones which, being developed in perichondrium, are easily removed from the macerated skull, are the parietals, the frontals, the bones 1.1. and 2.2. (Fig. 23), the squamosals (when these are not anchylosed with the opisthotic bones),[1] the vomer, and the parasphenoid.

The bones which, as ossifications of the substance of the cartilaginous cranium itself, are not thus separable, are the basi-, ex-, and supra-occipitals, the three periotic bones, the ali-sphenoids, the basi-sphenoid, the post-frontals, the pre-frontals, the bones 3.3 (Figs. 23 and 27).

Thus, in a certain sense, the adult skull of the Pike may be said to represent, in a persistent form, a condition of the skull which is transitory in Man.

Let the sides of the human fœtal cartilaginous cranium grow up and unite in the roof of the skull; let the pre-sphenoidal, ethmoidal, and internasal portions be greatly elongated; let no distinct ossification take place in the pre-sphenoidal and orbito-sphenoidal regions, or in the part answering to the lamina perpendicularis, while the basi-sphenoidal ossification remains very small, and that cranium would put on the most important and striking characters of that of the Pike.

[1] How far the bone which I have marked *Sq.* in the skulls of Fishes is really a membrane bone and the homologue of the squamosal of Reptiles, Birds, and Mammals, is a question which needs thorough re-investigation. Mr. Parker is of opinion that it is really a cartilage bone and the homologue, not of the squamosal, but of an independent ossification, which he finds well developed in the periotic capsule of the Mole and Shrew and terms the "pterotic."

IV. THE SKULLS OF FISHES

It has been seen that the skull of Man and that of the Pike agree in passing, in a similar order, through similar developmental stages. Each, at first, is a *membranous cranium*, its walls being composed of indifferent tissue, with the exception of that small part of its base which is occupied by the notochord. The greater part of the substance of each becomes chondrified, and thus that *cartilaginous cranium* is produced, which is a temporary structure in the Man, but a persistent one in the Fish. Neither in the membranous, nor in the cartilaginous state, does the cranium of either Man or Fish present any trace of that segmentation which becomes obvious in the third condition, when, by the deposit of calcareous salts around certain centres, either in the cartilaginous cranium or the adjacent membrane, the *bony cranium* is developed.

These three conditions of the skull are manifested, in the same order of succession, by all vertebrate skulls which become completely ossified; but the crania of many vertebrated animals remain throughout life in the second state, or in a condition intermediate between that and the third, while the skull of one of the *Vertebrata* persists in a state which can only be regarded as a modification of the membranous cranium. Hence I shall proceed to describe the leading modifications of the Vertebrate Skull under these heads:—A. The *membranous cranium*. B. The *cartilaginous cranium*. C. The *cartilaginous cranium, with superadded membrane bones, but no cartilage bones*. D. The *osseous cranium*.

The three first-mentioned kinds of skull are met with only among fishes; *Amphibia, Reptilia, Aves,* and *Mammalia* invariably possessing a larger or smaller number of cranial bones developed in cartilage.

A. *The membranous cranium.*

The only animal, at present known, which comes under this category is that singular fish, the lowest of all *Vertebrata*, *Amphioxus lanceolatus* (Fig. 28). The notochord (*Ch*), surrounded by a merely membranous sheath, extends very nearly

to the anterior pointed extremity of the body. The myelon, or spinal chord (*My*), occupies the ordinary position above it, in a canal formed by upward processes of the membranous sheath, and gives off the spinal nerves, *d d*, on each side. Quadrate masses of somewhat denser tissue, *e e*, seem faintly to represent neural spines. Just above the anterior boundary of the mouth, but far behind the anterior end of the notochord, the myelon, dilating very slightly, suddenly terminates, and with it, the

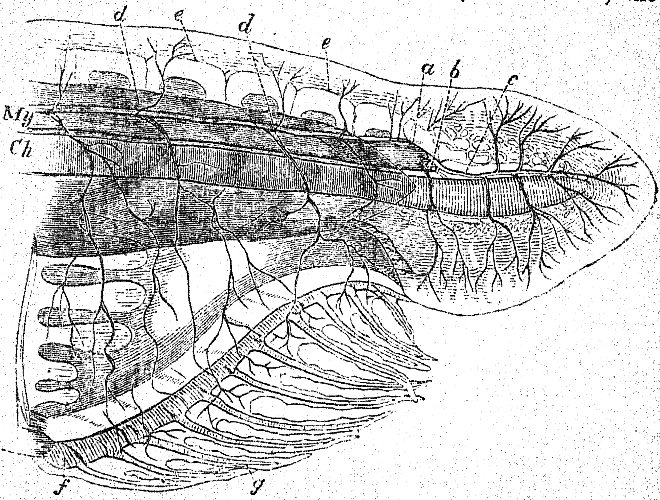


Fig. 28.—Skull of *Amphioxus lanceolatus* (after Quatrefages).—*a*, Position of olfactory (?) sac; *b*, optic nerves; *c*, fifth (?) pair; *d*, spinal nerves; *e*, representatives of neural spines; *f*, *g*, oral skeleton; *Ch*, notochord; *My*, spinal chord, or myelon.

neural canal. The lateral muscles are divided into segments corresponding with the pairs of spinal nerves, and the most anterior of these segments is situated just behind the slightly dilated chamber of the neural canal which contains the correspondingly enlarged end of the nervous axis. The latter is all that represents the brain, and the chamber is the skull.

A ciliated sac placed at *b*, in connection with the upper surface of the brain, has been considered to be the olfactory organ of this fish, but it is possible the sac may simply represent the pineal body; optic nerves (*b*) are given off to the rudimentary

eyes, and the branches (*c*) appear to be analogous in function to the fifth pair. But no pituitary body has been recognised, and, what is still more singular, there is no trace of auditory sacs. A cartilaginous ring, provided with tentacular prolongations (*f*, *g*), surrounds the mouth, and there is a singular branchial skeleton more like that of an Ascidian than any ordinary vertebrate structure; but neither of these structures probably have anything to do with the true cranial or facial skeleton.

It will be observed that this very remarkable skull, if it can be properly so called, is not strictly comparable to an arrest of

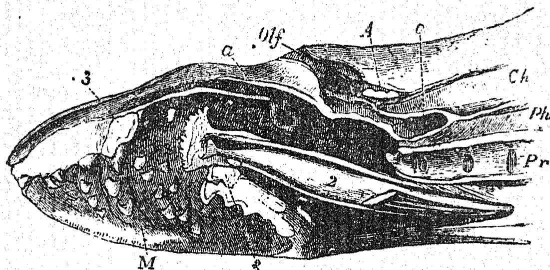


Fig. 29.—Vertical and longitudinal section of the anterior part of the body of a Lamprey (*Petromyzon marinus*).—*A*, the cranium, with its contained brain; *a*, section of the edge of the cartilage marked *a* in Fig. 30; *Olf*, the entrance to the olfactory chamber, which is prolonged into the cæcal pouch, *o*; *Ph*, the pharynx; *Pr*, the branchial channel, with the inner apertures of the branchial sacs; *M*, the cavity of the mouth, with its horny teeth; 2, the cartilage which supports the tongue; 3, the oral ring.

development of a higher vertebrate skull; the notochord extending far beyond the end of the cranium, which it never does in any embryonic condition of a higher Vertebrate.

B. *The Cartilaginous Cranium.*

Of this there are three forms: in the first (*a*) there is no mandible; in the second (*b*) the mandible is present, and the suspensory apparatus by which it is connected with the skull forms one mass with the latter; in the third (*c*) the mandible is also present, but the suspensory apparatus by which it is connected with the skull is freely movable.

a. The cartilaginous cranium without a mandible.

This kind of cartilaginous cranium is found only among the

Marsipobranchii, or Lampreys and Hags, and a description of its characters in the former will suffice to illustrate its nature. Fig. 29 represents a vertical and longitudinal section of the anterior part of the body of the large Sea Lamprey (*Petromyzon marinus*), and gives a very good notion of the excessively minute proportions of the proper skull (A) to the rest of the body in this

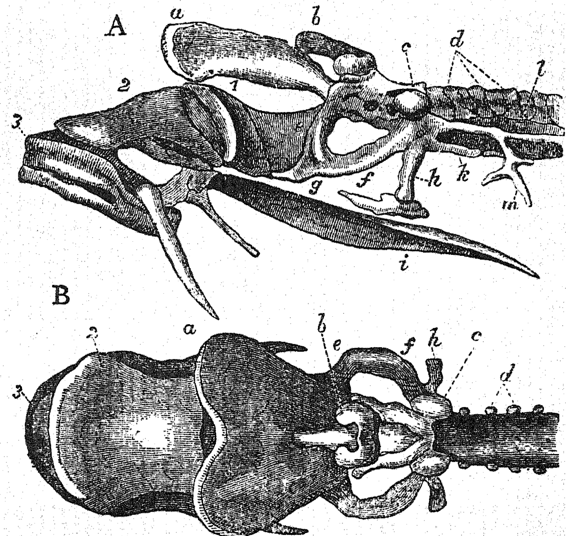


Fig. 30.—A, the skull of a Lamprey viewed from the side; B, from above (after Müller).—*a*, the ethmo-vomerine plate; *b*, the olfactory capsule; *c*, the auditory capsule; *d*, the neural arches of the spinal column; *e*, the palato-pterygoid portion; *f*, the hyomandibular and symplectic portion, and *g*, the quadrate portion of the sub-ocular arch; *h*, stylo-hyal process; *i*, lingual cartilage; *k*, inferior, *l*, lateral prolongation of the cranial cartilage; 1, 2, 3, accessory labial cartilages.

animal. A and B (Fig. 30) are lateral and superior views of the skull with its accessory cartilages, separated from the soft parts. The notochord (*Ch*) is, as in *Amphioxus*, exceedingly large, and is surrounded by a merely membranous sheath, from which prolongations are given off above to form the sides of the small neural canal. In the walls of this canal, cartilaginous rods, which represent neural arches, are developed, and it dilates more distinctly in the head than in *Amphioxus*, though the cranial

cavity is still very minute. The myelon also undergoes a very distinct enlargement as it enters the cavity, and all the typical divisions of the vertebrate encephalon are recognisable in the brain thus formed.

The notochord terminates in a point immediately behind the pituitary body. As it approaches the cranium, a rod of cartilage (*l*, Fig. 30, A) is developed on each side in the lateral parts of its sheath, and gives attachment to the branchial skeleton (*m*); still more anteriorly two other cartilaginous filaments (*k*) appear, side by side, in the under region of the sheath. These pass into the hinder part of the proper cranium, which is a sort of cartilaginous box, closed in front, and through the greater part of its roof, only by membrane, but complete behind, where it arches over the myelon, and is perforated by the occipital foramen. The postero-lateral parts of this cranium are dilated to give rise to the two oval auditory capsules (*c*), and beneath these they are produced into two processes, *h* and *f*, which have a common base, but diverge from one another below. The process *h* gives attachment to a cartilage which is connected with that supporting the tongue (*i*). The process *f*, on the other hand, passing downwards and forwards, becomes continuous at *g*, with another bar of cartilage *e*, which is connected with the antero-lateral part of the skull beneath the olfactory capsule. The eye lies over the triangular space inclosed between the sides of the skull and these two processes, so that *e*, *g*, *f* may be termed the *sub-ocular arch*.

If the skull is viewed from below, the processes *e* and *e* of opposite sides are seen to be continued into one another by a transverse band of cartilage, which forms the proper anterior boundary of the skull. The front edge of this band, which Müller calls the "hard palate," articulates with the broad and expanded cartilaginous plate (*a*). The common roots of the processes *f* and *h* are also continued into a "basi-occipital" plate of cartilage, but, between this plate and the "hard palate," there is an oval space through which the neck of the long olfactory cæcum (*o*, Fig. 29) passes. This cæcum, therefore, separates the front part of the floor of the cranial cavity, which is simply membranous, from the so-called "hard palate." On comparing this skull with that of the embryonic fish (see Fig. 26), *h* obviously answers to the stylo-hyal cartilage; *f*, to the ascending posterior crus of the palato-quadrate inverted arch and the hyomandibular cartilage; *e*, to the ascending and anterior crus of the same. It is true that no natural division of the arch into

palato-quadrate and hyomandibular (and symplectic) portions occurs in the lamprey, but this is only one of several respects in which the Marsipobranchs resemble *Amphibia* rather than osseous fishes. The inverted cartilaginous arch which gives attachment to the hyoidean and mandibular apparatuses of a tadpole is strictly comparable to the arch (*e, g, f*) in the lamprey. The margins of the oval space upon the base of the skull answer to the divergent *trabeculæ cranii*, and the plate *a* to the ethmo-vomerine cartilage. The remarkable and apparently anomalous separation of the *basis cranii* into an upper membranous and a lower cartilaginous part, by the interposition of the backward

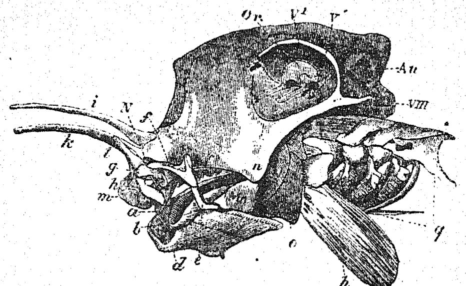


Fig. 31.—Skull of *Callorhynchus Antarcticus* (after Müller).—*a*, anterior tooth of the upper jaw; *c*, posterior tooth; *b*, mandibular tooth; *d, e, f, g, h, i, k, l, m*, accessory labial, nasal, and rostral cartilages; *n*, quadrate portion of the sub-ocular plate which supports the hyoid (*o*) and the mandible (*Mn*); *p*, the representatives of branchiostegal rays; *q*, the branchial arches; *Au*, auditory region; *Or.*, orbit; V^1, nasal division of the fifth nerve.

prolongation of the olfactory chamber, seems to me to be comparable to that separation of the upper and lower walls of the pre-sphenoid, basi-sphenoid, and even of the basi-occipital, by a backward extension of the olfactory cavities, which takes place in so many of the *Mammalia*. On the other hand, I doubt whether the accessory buccal cartilages, 1, 2, 3, etc., can be strictly compared with anything in other fishes, though some of them are doubtless, as Müller has suggested, the analogues of labial cartilages.

b. The cartilaginous cranium with a mandible and a fixed suspensorium.

The *Holocephali*, or Chimæroid fishes (*Chimæra* and *Callorhynchus*) present this type of cranial organisation. In accord-

ance with the large development of the brain, the skull of these fishes has attained a great advance in dimensions over the spinal column, and presents a large internal chamber. It is a continuous cartilaginous mass, without any superior aperture of sufficient size to deserve the name of a fontanelle, in the base of which the notochord does not persist, and which is definitely articulated by two lateral convex facets and a median concave surface on the hinder margin of its floor (*A*, Fig. 32) with the anterior segment of the spinal column.

The skull is high and compressed from side to side; posteriorly,

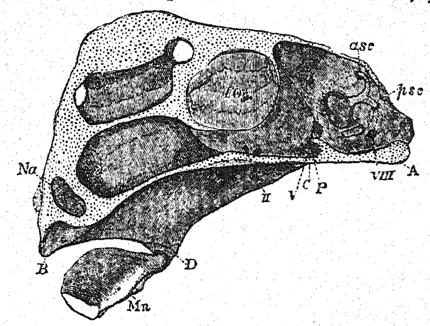


Fig. 32.—Vertical section of the skull of *Chimæra monstrosa* without the labial and nasal cartilages.—*A*, the basi-occipital region; *P*, the pituitary fossa; *Na*, the partition between the two olfactory sacs; *B*, the alveolus for the anterior upper jaw tooth; *I.Or.*, the inter-orbital septum; *asc*, *psc*, anterior and posterior vertical semicircular canals; *I.*, *II.*, *V.*, *VIII.*, exits of the olfactory, optic, fifth, and eighth pairs of cerebral nerves.

it exhibits, on each side, an enlargement (*Au*), which lodges the auditory organ. In front of these are the large orbits (*Or.*), separated by a thin membranous inter-orbital septum (*I.Or.*), which is unlike the inter-orbital septum usually met with, in that it lies above, and not below, the forward continuation of the cranial cavity (Fig. 32). Usually, an inter-orbital septum is formed by the compressed floor of the skull; here it is constituted by the compressed roof. Two chambers for the olfactory sacs (*N*, *Na*) terminate the skull anteriorly and inferiorly; and they, the lips and the anterior part of the snout, are protected and supported by a number of accessory cartilages (*d* to *m*).

Below the auditory and orbital regions, and in front of the latter as far as the nasal capsules, the base of the skull gives off

a broad cartilaginous sub-ocular plate (*C*, *D*, Fig. 32), the two edges of which, sloping towards one another, bring it to a point at *n* (Fig. 31; *D*, Fig. 32). With this part of the plate the mandible (*Mn*) is articulated, while to the middle of its posterior margin (*D*, *C*, Fig. 32) the hyoidean apparatus (*o*, Fig. 31) is attached.

A vertical section of the skull (Fig. 32) shows that the proper cranial cavity consists of a large posterior chamber, divided by a long and comparatively narrow neck from a much smaller, but still large, anterior chamber. The latter contains the olfactory lobes, and presents on each side, in front, a sort of cribriform plate, through which the filaments of the olfactory nerve pass to the nasal sacs. The commencement of the narrow neck is perforated on each side by the optic foramina (*II.*). The hinder dilatation contains the mass of the brain, and, on each side, chambers for the auditory organs, which communicate with it, are situated. The posterior edge of the inter-orbital septum bounds this chamber in front, above the "neck." In front of the anterior boundary of the inter-orbital septum, and above the olfactory division of the skull cavity, there is a curious chamber filled with fatty matter, and open in front and behind, which is traversed by the nasal division of the fifth nerve.

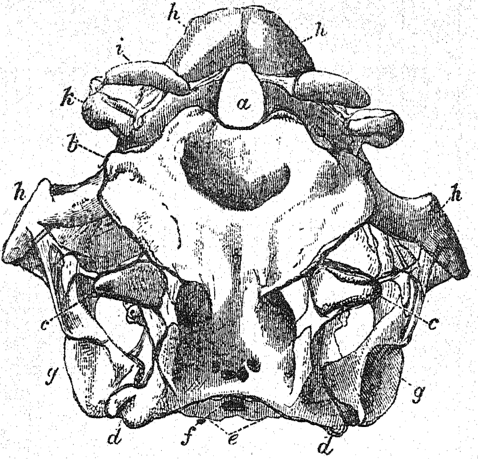
Müller well says, "The skull of *Chimæra* is most like that of a tadpole;" [1] but if we interpret the former strictly by the latter, as I believe ought to be done, the results will be somewhat different from those at which Müller arrives. The plate *C*, *D* answers precisely to the sub-ocular arch of the lamprey and to the corresponding arch in the tadpole's skull, though it is chondrified throughout, and not perforated by a large aperture, as in the two latter animals. But, admitting this, the further development of the frog proves that the sub-ocular arch answers to the common suspensorium of the hyoid and mandible, and to the palatine, pterygoid, and quadrate bones; and that it has nothing to do with the maxilla or premaxilla. The large posterior upper jaw teeth of the Chimæroids (*c*), therefore, being attached to the under surface of the anterior part of the sub-ocular plate, must be palatine or palato-pterygoid teeth. The small anterior teeth (*a*), on the other hand, are fitted into fossæ, or alveoli (*B*), which are situated immediately under the floor of the nasal chambers, in the vomerine region of the skull, and must be regarded as vomerine teeth—as, indeed, Cuvier suggested. On the other hand, I think Müller's view that the cartilages

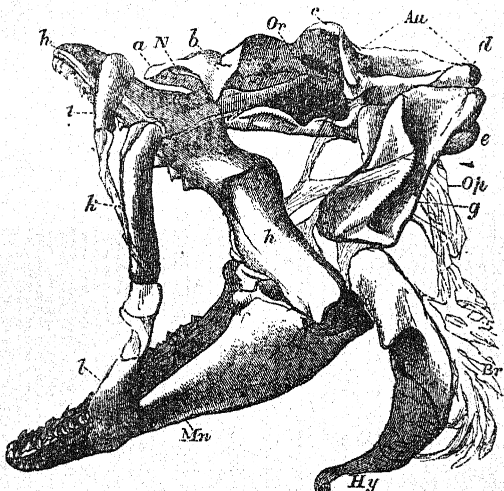
[1] Vergleichende Anatomie der Myxinoiden. Erster Theil, p. 159.

(*d*, *e*, etc.) are accessory labial cartilages, and not, as Cuvier supposed, representatives of premaxillæ, maxillæ, etc., has everything in its favour.

c. The cartilaginous cranium, with a mandible and with a movable suspensorium.

This form of cranium is met with in the sharks and rays, and may be illustrated by an account of that of *Squatina*, the monk fish (Figs. 33 and 34). The form of the skull is here the exact converse of that observed in the Chimæroids, being exceedingly broad and depressed, instead of high and compressed. The surface of the cranium is encrusted with a pavement of minute ossicles, arising from the ossification of the superficial layer of the cartilage. Behind, the basilar region of the skull presents two lateral articular surfaces to the front part of the spinal column, and exhibits the wide lateral expansions for the auditory organs (*Au*); at the sides of the skull, in front of these, lie the orbits (*Or*) bounded behind by the post-orbital processes (*c*), and by the antorbital, or prefrontal, processes (*b*) anteriorly. The latter divide the orbits from the nasal chambers (*N*), the apertures of which look downwards. The prefrontal processes are continued, on the inner sides of the nasal chambers, into a broad plate, emarginate anteriorly, which terminates the floor of the skull, and corresponds with the ethmo-vomerine part of the cartilaginous skull of the human fœtus or of the pike. The anterior part of the roof of the skull is not directly continued into the upper surface of the plate, but ends in a deeply concave edge; the vacuity, or fontanelle, is occupied by fibrous tissue in the recent state. Small apertures upon the roof of the occipital region communicate with the auditory chambers. The upper end of a stout prismatic cartilage (*g*) is movably articulated with the outer wall of the auditory prominence. The lower end of this cartilage is united by ligaments behind to the hyoidean arch (*Hy*), and in front to the upper and lower dentigerous arches (*h* and *Mn*). Each of these arches is composed of two pieces united in a median symphysis, and the under surfaces of the outer and posterior ends of the upper arch are articulated with the upper surfaces of the outer and posterior ends of the lower arch. The upper arch is, in addition, articulated with the under surface of the prefrontal region of the skull. Three cartilages (*i*, *k*, *l*), connected together by ligaments, lie outside the dentigerous arches, two, on each side, being superior and one inferior. Furthermore, cartilaginous filaments (*Op*) are attached to the





Figs. 33 and 34.—The skull of *Squatina* viewed from above (Fig. 33), and from the side (Fig. 34).—*a*, vomerine region; *b*, prefrontal; *c*, post-orbital; *d*, post-auditory processes; *e*, occipital condyles; *f*, occipital foramen; *g*, suspensorium; *h*, upper dentigerous arch; *i*, *k*, *l*, labial cartilages; *Mn*, mandible; *Au*, auditory chamber; *Or*, orbit; *N*, nasal chamber; *Op*, opercular cartilaginous filaments; *Br*, branchio-stegal rays; *Hy*, hyoidean arch.

hinder edge of the prismatic cartilage (*d*), and to the hyoidean arch (*Br*).

The interpretation of the cartilages (*i, k, l*) has been a matter of much controversy. In a remarkable essay published in the first volume of the "Mémoires du Museum," Cuvier proposed to consider the upper dentigerous arch (*h*) as the homologue of the palatine and pterygoid bones of osseous fishes, the cartilages (*i, k*) as the premaxilla and maxilla. The suspensorium (*g*) he considered to be the homologue of the hyomandibular, symplectic and metapterygoid. The lower dentigerous arch (*Mn*) was obviously the mandible.

On this latter point all anatomists are agreed; but, in his famous "Comparative Anatomy of the Myxinoid Fishes," Johannes Müller—guided, like Cuvier, by purely anatomical considerations, and by what I have elsewhere termed the method of gradation—proposed a totally different interpretation of the other parts. According to this view, *i, k,* and *l* are merely labial cartilages, and therefore do not represent the premaxilla and maxilla. Again, Cuvier had greatly relied upon the absence of any parts on the inner side of *h* which could answer to palatine or pterygoid elements, in arguing that *h* itself represents them. But Müller adduced his own and Henle's observations to prove that in a great many Plagiostomes, particularly the Rays, such cartilages, situated on the inner side of the upper dentigerous arch, do occur, and thus arrived, by a line of argumentation precisely as legitimate as that of Cuvier, at the exactly opposite result—that *h* represents the premaxilla and maxilla, and not the palatine or pterygoid.

The fact that these opposing views were entertained by men like Cuvier and Müller is evidence that each had much in its favour; but, in truth, neither was free from grave difficulties. Thus neither accounted for the articulation of the mandible with the upper dentigerous arch—a relation into which the mandible never enters either with the palatine, or with the maxilla, in the vertebrate series; and as Müller himself is forced to admit that some of the cartilages on the inner side of the upper dentigerous arch are accessory, why should not all be so?

This is just one of those cases in which the study of development manifests its full importance, and decides, at once, problems which, without it, might be the subjects of interminable discussion. A comparison of the skull of the monk fish with that of the embryonic osseous fish (Fig. 26, C) seems to me to demonstrate

beyond question, that the upper dentigerous arch (*h*) corresponds with the palato-quadrate cartilage of the embryo,[1] and that the suspensorium (*g*) equally corresponds with the hyomandibular and symplectic cartilage. But in this case Cuvier's view of the upper dentigerous arch must be regarded as a singularly near approximation to the truth, for it certainly answers to the palatine and pterygoid; though, in addition, it contains the representatives of the quadrate and metapterygoid bones of the osseous fish. And his opinion regarding the nature of the suspensorium was still nearer to what I believe to be right. On the other hand, I think it very probable, though not certain, that as Müller supposed, the cartilages (*i, k, l*) are merely labial, and that these fishes have no representatives of the premaxilla and maxilla. But the so-called palatine and pterygoid cartilages of Müller, if the view I take is correct, are as much accessory parts as the spiracular cartilages, and, like them, have no representatives in osseous fishes.

V. THE SKULLS OF FISHES AND AMPHIBIA

C. *The cranium, consisting chiefly of cartilage and without cartilage bones, but with superadded membrane bones.*

The skulls of the chondrosteous Ganoids, the Sturgeons, and *Spatulariæ* exemplify this type of structure, which forms a most interesting transitional link between the skull of Plagiostomes and the skull of ordinary osseous fishes.

Spatularia has a completely cartilaginous skull, produced in front into a great beak, flattened from above downwards. The cartilaginous representatives of, at fewest, seven of the anterior vertebræ of the spinal column coalesce into one mass with one another and with the skull. The notochord, extremely large in the spinal column, rapidly diminishes in size as it enters the skull, and, becoming a mere thread, terminates behind the pituitary fossa. The auditory organs are contained in large postero-lateral projections of the cranial mass, with the outer sides of which the suspensoria are connected. The base of the skull is protected by a long parasphenoid, which extends back under the anterior part of the spinal column; in the dorsal

[1] Rathke arrived at this conclusion also, on developmental grounds, in 1839. See his "Vierter Bericht," quoted in the last Lecture of this work.

region it presents an anterior and a posterior pair of perichondrial ossifications, separated by oblong laminæ from lateral bony plates of the same character, but the homology of these bones with those in the roof of the Teleostean skull is not, to my mind, satisfactorily made out.[1]

The suspensorial appartus of *Spatularia* consists of a single bone (*A*), compressed from above downwards superiorly, and from side to side inferiorly, with a superior and an inferior cartilaginous epiphysis; to the lower cartilaginous epiphysis the operculum (*Op*) is attached, and a short thick prismatic cartilage (*B*) is united by ligament with, and can play freely upon, its anterior and inferior angle. Posteriorly the lower end of this

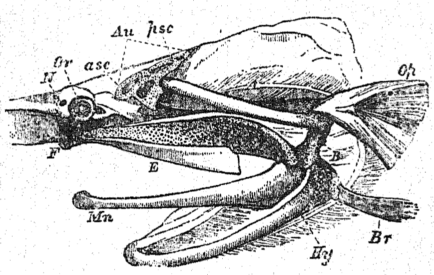


Fig. 35.—Side view of the skull of *Spatularia* with the anterior (*asc*) and posterior (*psc*) vertical semicircular canals exposed.—*Au*, the auditory chamber; *Or*, the orbit with the eye; *N*, the nasal sac; *Hy*, the hyoidean apparatus; *Br*, the representatives of the branchiostegal rays; *Op*, the operculum; *Mn*, the mandible.

cartilage (*B*) is connected by ligament with the hyoidean arch (*Hy*), which consists of two portions on each side; a small upper piece, with which the flat bone (*Br*), representing a branchiostegal ray, is connected; and a long lower ramus, the middle third of which is bony, while the two ends are cartilaginous.

Anteriorly, the lower end of the inferior suspensorial cartilage (*B*) is united by ligaments to two cartilaginous semi-arches (*D* and *Mn*), of which the upper (*D*) is articulated by a transversely convex head with a concavity of the lower (*Mn*). The upper semi-arch is ligamentously united to its fellow in the middle line, and is suspended by ligamentous fibres to the under part of the prefrontal region of the skull. A long flat bone (*E*),

[1] See "Spatulariarum Anatomiam descripsit Tabulaque illustravit Albertus Wagner." Berolini, 1848.

the hinder end of which is cut off in the specimen figured, lies on the outer side of the cartilage (*D*), and extends to the middle line. A second long flat bone is closely applied to the inner surface of the cartilage and follows its curves, from its hinder to its anterior extremity, overlapping and folding over the upper edge of the anterior three-fifths of the cartilage. Between the hinder part of *E*, here cut away, and *D*, is a space occupied by the levator muscle of the lower jaw.

The mandibular cartilage extends to the symphysis, and is coated externally, and partially embraced by, the flat bone (*Mn*), the greater part of the upper edge of which bears teeth.

On comparing these parts with those of the corresponding apparatus in the embryonic fish (Fig. 26), it becomes clear that

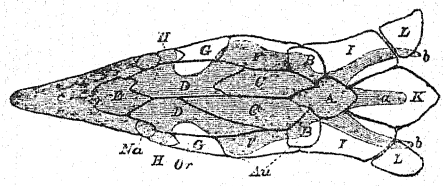


Fig. 36.—The cartilaginous skull of a Sturgeon, with the cranial bones. The former is shaded, and is supposed to be seen through the latter, which are left unshaded.—*a*, ridge formed by the spinous processes of the anterior vertebræ, which have coalesced with one another and with the skull; *b*, lateral wing-like processes; *c*, rostrum; *Au*, position of the auditory organs; *Na*, position of the nasal sacs.

the pieces *A* and *B* answer to the hyomandibular and symplectic, taken together. Indeed, at first sight, *A*, supporting as it does the operculum, seems to answer to the hyomandibular, and *B* to the symplectic itself; but then it may be suggested that the hyoidean apparatus is attached at the distal end of *B*, and not between it and *A*, as it would be if the two corresponded, respectively, to the hyomandibular and symplectic.

The cartilage *D* obviously answers to the palato-quadrate arch, and that of the lower jaw to Meckel's cartilage. The fact that a levator muscle of the lower jaw passes between *E* and *D* seems to prove the former to correspond with a maxilla; in which case the internal bone would be a sort of palatopterygoid, similar to that we shall meet with in *Lepidosiren*.

The skull of the Sturgeon (*Accipenser*), like that of *Spatularia*, is greatly enlarged, posteriorly, by the coalescence with it, and

with one another, of six or seven of the anterior vertebræ. In front, it is prolonged into a triangular snout or beak (*c*, Fig. 36; *a*, Fig. 37), the wide base of which is formed by the antorbital, or prefrontal, prominences which separate the olfactory chambers from the orbits. Behind the latter are the two great projections (*c*, Fig. 37) which contain the auditory organs; and behind these again, and separated from them by a deep lateral fossa, are two wing-like processes (*b*, Fig. 36), which are directed outwards and obliquely backwards, and proceed, not from the walls of the cranium proper, but from those of the spinal column, where it joins the skull. At this point there is, in the craniospinal cartilage of both the Sturgeon and the *Spatularia*, a great dilatation of the neural canal, which is closed above only by a membraneous fontanelle. The skull proper has no such fontanelle. There is a well-marked pituitary fossa, and the notochord, very thick in the spinal column, tapers to a thread as it enters the base of the skull, and ends behind this fossa.

The bones which are developed in relation with this cartilaginous cranium in the base of the skull are—a great parasphenoid which extends back under the coalesced anterior vertebræ, and forwards to the level of the nasal cavities; and a slender median bone in front of this, which underlies the rostral prolongation (*c*), and appears to represent the vomer.

No distinct ossifications protect the lateral walls of the skull, but the bones marked *F* (Fig. 36) send down processes for a short distance, and the parasphenoid gives off transverse prolongations upwards and outwards, from each side of the middle of its length, as in most fishes.

The roof of the skull presents a number of distinct flat ossifications, no one of which involves the subjacent cartilages, and which vary very much in contour and extent in different specimens. The general arrangement is, however, fairly represented by the accompanying figure (Fig. 36).

Of these bones, the pairs *C*, *C* and *D*, *D* clearly represent, both in position and character, the parietal and frontal bones of the pike, while *F*, *F* similarly correspond with the squamosals of that fish.

In position, again, *E* answers to the ethmoid, *H*, *H* to the prefrontals, *G*, *G* to the post-frontal, *B*, *B* to the epiotics, and *A* to the supra-occipital of the Pike. But every one of these is a membrane bone, and not, as are the corresponding elements of the Pike's skull, a cartilage bone.

These bones are therefore, strictly speaking, the analogues, and not the homologues, of the bones to which they appear to answer in the Pike, though hitherto no distinction has been drawn between the two.

K and *I*, *I* are bones which do not properly belong to the skull, but which, as happens among many Siluroid *Teleostei*, are anchylosed with the cranium. *K* is the most anterior of the median dermal scutes, and *I*, *I* are the supra-scapular bones. The letters *L*, *L* indicate the scapular bones movably united with these last.

The suspensorium of the Sturgeon consists of a large, irregularly-prismatic body, composed of a bony central piece (*f*, Fig. 37) with two cartilaginous epiphyses, the lower of which (*g*) is much the longer, and is connected by ligament with another

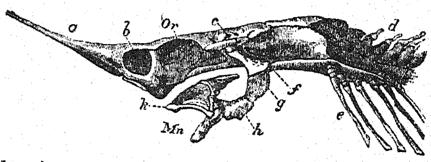


Fig. 37.—Side view of the cartilaginous cranium of *Accipenser* (after Müller).—*a*, rostrum; *b*, nasal chamber; *Or*, orbit; *c*, region of the auditory organ; *f*, *g*, *h*, suspensorium; *k*, maxillo palatine apparatus; *Mn*, mandible.

cylindrical cartilage (*h*), while the upper articulates with the outer and under part of the auditory capsule. Rather above the letter *h*, the lower cartilage gives attachment to a cartilaginous nodule with which the principal piece of the hyoidean arch is connected.

At its distal end the cylindrical cartilage (*h*) is united by ligaments to the two apparatuses *k* and *Mn*. Of these, *k* may be described as a rhomboid, composed partly of cartilage and partly of bone, and so bent as to assume a transversely arched form. Its outer angles present convex articular facets to concavities on the lower arch (*Mn*), which last, composed of a single bony ramus on each side, is undoubtedly the mandible. The cartilaginous basis of *k* is strengthened by eight bones, four on each side. Of these, two lie altogether external to the cartilage, and leave between themselves and it an interspace, in which the levator muscle of the lower jaw lies.

The other pair consist, firstly, of a large bone, which lies,

for the most part, internal and inferior to the cartilage, and extends from the inner side of the articular process for the lower jaw, upwards and inwards, to meet its fellow, posteriorly; forwards, to articulate with the anterior of the external bones. And, secondly, of a small bone fitted on to the anterior and external edge of this, and to the inferior surface of the anterior external bone. The whole apparatus, *k*, is very loosely connected with the skull, so that it is capable of being protracted and retracted with great freedom.

The general relations of this singular mechanism to the manducatory organs of ordinary Teleostean fishes appears to be rendered evident by the same method as that which has been employed to demonstrate the nature of the jaws of the Plagiostomes. The osseo-cartilaginous structure, *k*, answers to the palato-quadrate arch of the Sharks and Rays, or to the palato-quadrate cartilage of the embryonic fish; and *f*, *g*, *h* correspond with the undivided suspensorium of the Sharks and Rays, and with the hyomandibular and symplectic cartilages of the embryo Teleostean. Furthermore, on comparing *k* with the maxillary apparatus of *Spatularia*, the cartilaginous basis appears to answer to the cartilages (*D*, *D*) of that fish joined together; while the anterior outer bone in the Sturgeon is the equivalent of the bone *E*, and may be regarded as a maxilla. The two internal bones correspond with the inner bone of the Spatularia's jaw. The Sturgeon, however, more nearly approaches ordinary fishes in the development of an anterior or palatine element, distinct from the posterior or pterygoid element. As for the small external bone, which passes obliquely from the end of the maxilla to the outer surface of the cartilage, it is possibly a quadrato-jugal.

D. *The cranium consisting of cartilage to a greater or less extent, but with cartilage bones as well as membrane bones.*—The class *Pisces* presents us with a complete series of these crania, from the least ossified forms, which possess only one or two pairs of cartilage bones in the walls of the cranium, to the completely ossified skulls of the Cyprinoids and Siluroids. And, again, just as among the preceding groups we found that the Chimæroids differed widely from the rest in having the subocular process, or arch of the skull, to which the mandible is attached, formed of one piece of cartilage, which is continuous with, and immovable upon, the skull; so, in this series,

Lepidosiren is at once distinguished from all the rest by a similar character.

The skull of the Mudfish (Fig. 38) is composed of a framework of cartilage, which sends down a broad triangular process, on each side, to articulate with the mandible, and expands, posteriorly and laterally, into chambers for the auditory organs. Between these, the roof and the floor of the skull are both constituted by cartilage; but anterior to them, as far as the extremity of the parasphenoid (x), this tissue becomes very thin or disappears (Fig. 39). In front of the anterior end of the parasphenoid, it makes its appearance again on both the roof and the floor of the cranial cavity, beyond which it is continued

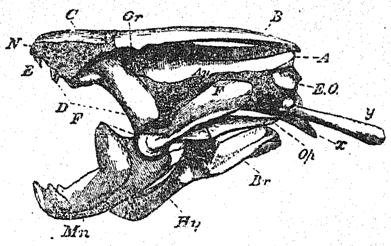


Fig. 38.—*Lepidosiren*. *A*, the parieto-frontal bone; *B*, the supra-orbital; *C*, the nasal; *D*, the palato-pterygoid; *E*, the vomerine teeth; *E.O.*, the ex-occipital; *Mn*, the mandible; *Hy*, the hyoid; *Br*, the branchiostegal ray; *Op*, the opercular plate; *x*, the parasphenoid; *y*, the bone which gives attachment to the scapular arch; *Or*, the orbit; *Au*, the auditory chamber; *N*, the nasal sac.

as a thin lamella to the end of the snout. A fibrous septum with a free concave, posterior margin, divides this region of the cranium into two lateral chambers, one for each olfactory lobe.

Behind the auditory chambers the cartilage is almost excluded from the walls of the skull by two lateral ossifications of its substance—the ex-occipitals (*E.O.*). As in the *Amphibia*, there is no ossified supra- or basi-occipital. The rest of the lateral parietes of the skull would be devoid of bony walls were it not that the parasphenoid (x) and the great bone (A), which roofs in the whole length of the skull, and answers to the frontals and parietals, send upwards and downwards, respectively, lateral processes, which unite together, and so replace the alisphenoid (Fig. 39). The ethmo-vomerine cartilage (*Eth. Vo.*) bears, superiorly, the nasal bones (C), and inferiorly it carries

teeth (*E*). A long flat bone, pointed posteriorly (*B, B*), is attached to the hinder edge of the nasals, and roofs over the orbit and temporal fossa.

The notochord, which forms the chief axis of the spinal column of this fish, is continued into the base of the skull, and ends in a point about the level of the exit of the trigeminal nerves (*V*). There is neither basi-occipital nor basi-sphenoid, and the presphenoid is represented only by the cartilaginous floor at ($P.S^1$). The pterygo-palatine apparatus is represented, on each side, by the great dentigerous curved plate (*D*), which is applied to the inner surface of the cartilaginous sub-ocular process, abuts against the parasphenoid by its inner edge, and descends to the inner side of the articular condyle for the

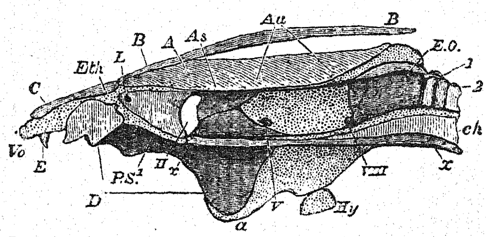


Fig. 39.—Longitudinal and vertical section of the Skull of *Lepidosiren*. The cartilage is dotted; the membraneous and bony constituents are shaded with lines. *A*, *B*, *C*, *D*, as in the preceding figure; *x*, *x*, the parasphenoid; 1, 2, the first and second vertebral arches; *Ch*, the notochord; *Au*, the situation of the auditory organ.

mandible (*a*). The hyoidean arch (*Hy*) is attached to the middle of the posterior and inferior edge of the sub-ocular cartilage, to the posterior part of the outer surface of which is applied the bone (*F*, Fig. 38) with which the opercular bone (*Op*) is movably united by ligament.

The bone (*F*) has, like most of the bones of the *Lepidosiren*, a green colour. Through the greater part of its length it is so easily separated from the cartilage that it is clearly a membrane bone. Towards the condyle, however, it adheres firmly to, though, on the application of a certain force, it springs away from, a nodule of whitish bone, which lies in the very substance of the articular end of the cartilage, and repeats its pulley-like form. I suspect that this nodule, which represents the *os quadratum*, is primitively distinct from the bone (*F*). The

latter, under these circumstances, would have much analogy with the pre-operculum of osseous fishes, and *Op* would correspond with the sub- or inter-operculum.

All other fishes, comprising such *Ganoidei* as have not been already mentioned, and the *Teleostei*, have, so far as is at present known, the palato-quadrate arch primitively distinct from the hyomandibular suspensor; the latter is, primitively, movable upon the skull; and, in the walls of the cranium, the pro-otic bones, at least, are ossified as well as the ex-occipitals; that is to say, they are constructed essentially upon the plan of the Pike. The modifications they exhibit in detail are almost infinite, but a few of the most important may be enumerated:—

1. The cartilaginous cranium persists throughout life in such fishes as the Pike and the Salmon; in very many, as the Perch and the Carp, it disappears almost entirely.

2. In most fishes the *basis cranii* is compressed from side to side in the orbital region, and vertically enlarged, so as to form an inter-orbital septum, which, as it were, encroaches upon the cranial cavity and narrows it anteriorly. But in others—such as the Cyprinoids and the Siluroids—no inter-orbital septum is developed, the *basis cranii* remaining flat, and the cranial cavity of nearly equal size throughout.

3. The last-mentioned fishes have the cranial walls completely occupied by bone, distinct ossifications representing the alisphenoids and orbito-sphenoids.

4. The opisthotic bone, occasionally absent as a distinct ossification, is very small in some fishes, such as the Perch (where it is Cuvier's "*rocher*" or "*petrosal*"), but becomes very well developed in such genera as *Ephippus*, and attains an immense size in the *Gadidæ*.

5. The canal for the orbital muscles is absent in many fishes, such as the Cod tribe.

6. The most remarkable modification of the fish's cranium proper, however, is the want of symmetry produced in the flat fishes, or *Pleuronectidæ*, by a sort of twist, which affects the anterior and upper, but not the hinder and inferior, part of the skull. Thus, if the skull of a Turbot be examined, the supra-occipital will be found in its ordinary place; while the epiotics and squamosals are symmetrically disposed on each side of it, so that the skull, viewed from behind, is like that of any other ordinary osseous fish. The basi-occipital, parasphenoid, and

vomer are likewise arranged, as usual, along the median basal axis of the skull. The pro-otics and post-frontals are also nearly symmetrical, but the alisphenoids are thrown over to the left side, so that the anterior aperture of the cranial cavity, between the alisphenoids, lies no longer immediately over the para-sphenoid, but to the left of it. The left frontal sends down a long curved process, which joins with one from the prefrontal of the same side, and the two eyes come to lie in the secondary orbit, developed between the curved bony boundary thus formed and the median frontal crest.

7. An addition takes place to the posterior extremity of the skull, in many fishes, by the anchylosis with it, and with one another, of a variable number of vertebræ. Cartilaginous vertebræ, as I have already pointed out, coalesce with the cartilaginous skull in both *Accipenser* and *Spatularia*, and two or three bony vertebræ are anchylosed with the osseous skull in *Lepidosteus* and *Polypterus*. Whether a similar addition takes place in the other living ganoid, *Amia*, or not, I cannot say. In many Siluroids a great number of vertebræ become thus anchylosed with one another and with the skull.

8. In both Siluroids and Ganoids, again, an addition to the roof of the skull is effected by the coalescence therewith of the suprascapular bones, as well as, in some cases, of dorsal dermal bones.

9. But certain of the most striking modifications of the physiognomy of osseous fishes are the result of the prolongation of the region in front of the orbit, which may be effected in two very different ways. For example, it is chiefly the elongation of the premaxillæ and mandible which gives rise to the remarkable beak of the "sword-fish" (*Xiphias*); while, in *Fistularia*, the premaxillæ and mandible remain very short, but are thrust out to a great distance from the orbit, by the production of the nasal and vomerine regions, on the one hand, and of the bones of the suspensorium on the other.

10. In such fishes as *Syngnathus* and *Fistularia*, a line joining the articular socket of the hyomandibular with the condyle of the *os quadratum*, makes a very acute angle with the base of the skull. In most fishes this angle is more or less acute; but in *Polypterus*, and still more in *Muræna*, it becomes a right or an obtuse angle, the corner of the gape being thus thrown behind the eye, instead of being, as in most bony fishes, in front of it. We shall find a similar rotation of the distal end of the suspen-

sorium to take place in the series of the *Amphibia*, and in the passage from the tadpole to the adult state of the highest of these animals.

11. The connection of the palato-quadrate arcade with the hyomandibular and symplectic suspensor varies, from the firm sutural union which is observed in the Pike and most osseous fishes, to a bond which is hardly closer than that which obtains in the Plagiostomes and Sturgeons, in *Polypterus*. In *Lepidosteus*, except for the inter- and pre-operculum, the tie between the symplectic and the palato-quadrate bones would be very loose, the palato-quadrate arcade and the suspensor being, as it were, naturally dissected from one another.

In some *Plectognathi* and Siluroids, on the other hand, all these parts become firmly anchylosed together, and with the side walls of the cranium.

12. Finally, the multiplication of the bony constituents of the maxilla and the mandible in *Lepidosteus*—the conversion of the maxilla into a mere support for a tentacle in many Siluroids—the absence of branchiostegal rays, and the presence of two "jugular" plates between the mandibular rami in *Polypterus*, must not be overlooked even in this brief enumeration of a few of the most salient modifications of the skulls of osseous fishes.

THE SKULLS OF AMPHIBIA

In cranial structure, as in all the other more important features of their organisation, the *Amphibia* are closely allied to Fishes, and widely separated from the abranchiate *Vertebrata*.

As in Fishes, a single median membrane bone, or parasphenoid, is developed under the base of the skull, while no such median bone is found in the higher *Vertebrata*. Like *Lepidosiren*, the *Amphibia* have no ossified basi-occipital or supra-occipital, whereas all the abranchiate *Vertebrata* possess these bones.

Again, like *Lepidosiren* and many other Fishes, the *Amphibia* have no true basi-sphenoid, developed in the cartilage of the *basis cranii*; while all the abranchiate *Vertebrata* have that bone well developed.

The hyoidean apparatus is, in *Amphibia*, as in Fishes,[1] connected with a suspensorium common to it and the mandibular

[1] According to Stannius, however, the hyoidean arch is attached directly and independently to the skull in many Rays. See that author's admirable "Handbuch der Anatomie der Wirbelthiere," Erster Buch, p. 46.

apparatus. In all the higher *Vertebrata* the hyoidean apparatus, if it is attached directly to the skull at all, is united therewith separately and distinctly.

In all *Amphibia* which have ossified ex-occipitals, a condyle is developed on each, for articulation with the first vertebra of the spinal column; and the basi-occipital, remaining unossified, takes no share in the formation of these condyles. In all the higher *Vertebrata*, on the other hand, the bony basi-occipital takes a greater or less share in the formation of the occipital condyle, or condyles.

The skull of *Amphibia* resembles that of the Chimæroids and *Lepidosiren*, and differs from that of Teleostean, Ganoid, and Plagiostome fishes, in the absence of any natural division between the palato-quadrate and suspensorial cartilages.

Like the Carp and the Siluroids, the *Amphibia* are devoid of any inter-orbital septum, the cranial cavity remaining of tolerably even size from the occipital foramen to its anterior termination.

In the Frog (Fig. 40) the skull is roofed in by two long flat membrane bones (*Pa*, *Fr*), which correspond with the parietals and frontals, and, in fact, each originate in two distinct centres, one in front and one behind. In front of these are two other membrane bones (*Na*, *Na*), which have been variously interpreted, but which probably answer to the nasals. On the base of the skull is the long single parasphenoid (x), the hinder part of which is produced into two broad lateral processes, which underlie the auditory capsules.

When these membrane bones have been stripped off, a subjacent cartilaginous cranium becomes apparent, produced behind into two lateral enlargements, or tuberosities, for the auditory organs, and having certain fontanelles or membranous spaces in its upper wall (Fig. 41). In the substance of this cartilaginous cranium, posteriorly, are two ossifications, one on each side of the occipital foramen, which nearly meet in the middle line above and below. These, the ex-occipitals, bear the condyles for articulation with the atlas, and partly shelter the posterior portion of the auditory organ. The front and upper wall of each auditory tuberosity is also largely ossified, the resulting bone protecting the anterior part of the organ of hearing, and being perforated, or notched, for the transmission of the third division of the trigeminal. This therefore is, without a question, the homologue of the pro-otic bone of the fish and of Man.

A fifth ossification of the cartilage is the very singular bone (y) which Cuvier termed the *os en ceinture*, or "girdle bone," from its encircling the anterior part of the cranial cavity. This bone has somewhat the form of a dice-box, with one end divided by a longitudinal partition. The latter—the front part of the bone—extends into the prefrontal processes in some frogs, protects the hinder ends of the olfactory sacs, and is perforated by the nasal division of the fifth. The median partition there-

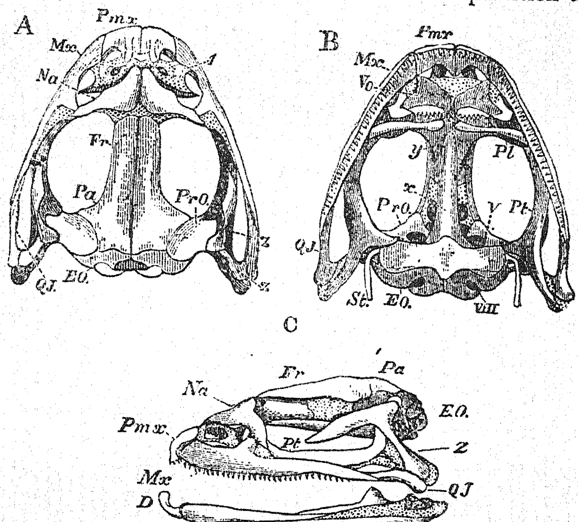


Fig. 40.—Skull of *Rana esculenta*. Seen A, from above; B, from below; C, from the side (after Dugès).—*x*, the parasphenoid; *y*, the girdle bone; *z*, the "temporomastoid" of Dugès.

fore must answer to some extent to the ethmoidal septum, while the lateral parts of the anterior division of the bone correspond with the prefrontals. On the other hand, the hinder division of the bone is an ossification of each wall of the cranium, in front of the exit of the optic nerves; so that I conceive this part of the bone can only answer to the orbito-sphenoids, united above and below. Upon this view of its nature, the girdle bone answers to at least five bones, viz., the ethmoid, prefrontals, and orbito-sphenoids.

No alisphenoid is developed in any Amphibian. There is

no separate opisthotic in the adult state, and I am not fully satisfied as to the existence of any distinct epiotic, though such a bone has been affirmed to exist (under the name of "mastoid") in the axolotl and the *Menobranchus*.[1]

The anterior part of the ex-occipital, in front of the foramen for the eighth nerve, which perforates that bone, probably represents the opisthotic, as between it and the posterior external margin of the pro-otic is placed the *fenestra ovalis*, a structure not met with in the class *Pisces*.

The facial bones are, for the most part, readily determinable; thus there can be no doubt about the premaxillæ (*PMx*), the maxilla (*Mx*), and the two large-toothed vomers (*Vo*). The

A B

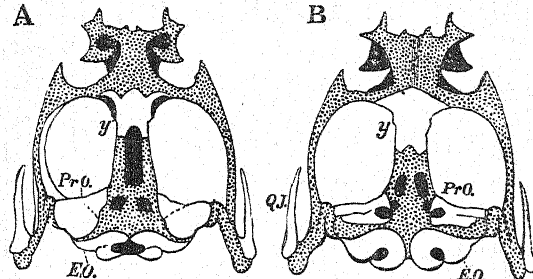


Fig. 41.—The Cartilaginous Cranium of *Rana esculenta*. A, from above; B, from below (after Dugès).—*y*, the girdle bone.

position of the posterior nares between the last-named bones and the bones (*Pl*) taken in connection with the relations of the latter to the prefrontal region of the skull, sufficiently defines the palatine character of *Pl*; while *Pt*, connected with the palatines on the one hand, and terminating on the inner side of the mandibular suspensorium on the other, corresponds as distinctly with the pterygoids of the higher *Vertebrata*.

The bone (*QJ*), which connects the end of the maxilla with the outer side of the suspensorium, appears to correspond with the quadrato-jugal of abranchiate *Vertebrata*.

It is more difficult to determine the nature of the bone *z*, the "temporo-mastoid" of Dugès, which is a long, hammer-shaped membrane bone, extending from the skull to the articular

[1] Mr. Parker informs me that the common Toad has a thin bony crest answering to the epiotic.

surface for the lower jaw, and sending a long process forwards over the temporal region.

When this bone, the pterygoids, palatine, quadrato-jugal, etc., have been removed, the cartilaginous cranium of the Frog (Fig. 41) is seen to give off from the outer ends of the prefrontal region and the auditory protuberances, two prolongations, the anterior of which curves round the orbit, and eventually unites with the posterior in the cartilaginous process which articulates below with the mandible, and unites by its upper or cranial end with the suspensor of the hyoidean apparatus (*St.*, Fig. 40).

This arch clearly answers to the sub-ocular arch of the Lampreys and to the sub-ocular cartilage of the Chimæroids and *Lepidosiren*, and corresponds with the palato-quadrate, hyomandibular, and symplectic cartilages of the embryonic osseous fish taken together. The distal end of this cartilaginous pedicle commonly presents a larger or smaller ossification of its substance, which represents the quadrate bone. Now, the problematical bone (*z*) lies on the outer side of the pedicle, and I was at one time inclined to think that it represented the hyomandibular bone of osseous fish—being largely led to that impression by the great size of the hyomandibular and the comparative minuteness of the quadrate in the Conger and the Murœnoid fishes. But the hyomandibular is an ossification in the cartilage of the suspensorium, not a membrane bone. The bone has been compared with the tympanic, but the tympanic membrane has a special and distinct supporting ring in the Frogs. It has been identified, again, with the squamosal, but it lies too far down on the outer side of the pedicle for that bone. Tracing the changes of form in this bone (which is very constant in the *Amphibia*) downwards to the *Menobranchus* and *Siren*, its resemblance in these perennibranchiates to the bone (*F*) of *Lepidosiren* becomes very striking; and I am disposed to identify it with that bone, which, as I have stated above, has much resemblance to the pre-operculum of osseous fishes.

The mandible of *Amphibia* is commonly composed of three pieces—a dentary, an angular, and an articular. The latter, always continuous with Meckel's cartilage, may itself remain persistently cartilaginous.

The skull of the tadpole, before ossification has commenced, presents a cartilaginous base, in which the notochord terminates in a point, immediately behind the pituitary fossa. At the sides, the basal cartilage expands into two oval auditory capsules, and

in front passes into the *trabeculæ cranii*, which embrace the membranous floor of the pituitary fossa, and reunite in the broad ethmo-vomerine cartilage. The apex of a sub-ocular arch, connected, behind, with the auditory region of the *basis cranii*, and, in front, with the prefrontal region, furnishes an articular surface to the axial, or "Meckel's cartilage," of the mandible. In the young Tadpole, a line drawn from the mandibular articulation to the auditory capsule makes an acute angle with the *basis cranii*; but, as age advances, the angle becomes more and more open, until, in the adult Frog, it is obtuse (Fig. 40), the articular surface for the mandible having passed far behind the auditory capsule. Of course the width of the gape increases *pari passu* with this rotation of the mandibular suspensor.

A survey of the series of the *Amphibia* from the perennibranchiates upwards, shows, in a persistent form, those inclinations of the suspensor which are transitory in the Frog. Thus in the perennibranchiate *Siren*, *Siredon*, *Proteus*, and *Menobranchus*, the angle is acute; in the Salamander and Salamandroid *Menopoma*, it is nearly a right angle; while, in the Frogs and Toads, and the ancient Labyrinthodonts, the angle is obtuse.

In the lower *Amphibia* there is no girdle bone, the orbitosphenoid and the prefrontals being usually represented by distinct bones. The frontals are distinct from the parietals, and the maxillary and pterygo-palatine arcades become imperfect.

Some of the Frogs and the *Cæciliæ*—the snake-like apodal *Amphibia*—have the cranial bones expanded and anchylosed into a sort of shield, presenting apertures only for the orbits and the nostrils; a process which is carried still further, by the addition of bones not known to existing *Amphibia*, in the extinct salamandroid members of the class, called Labyrinthodonts.

VI. THE SKULLS OF REPTILIA AND AVES

THE skulls of those abranchiate *Vertebrata* which do not suckle their young, and are oviparous, or ovo-viviparous, present certain peculiarities of construction in which they all agree with one another, and differ from the branchiate *Vertebrata* on the one hand, and from the *Mammalia* on the other.

Thus, the basi-occipital and the basi-sphenoid are always well

developed, and the former furnishes a large part of the occipital condyle, which is single and central.

There is no parasphenoid, or median membrane bone, underlying the base of the skull.

The lower jaw, each ramus of which is composed of several pieces, articulates with the quadrate bone, as in the branchiate *Vertebrata;* but the quadrate bone articulates directly with the cranial wall, and is not separated from it by any structure representing the hyomandibular bone.

It may probably be added that the basi-sphenoid is formed by the union of three ossifications of cartilage—one supero-median and two infero-lateral (the basi-temporals of Mr. Parker); but further research is required before this generalisation can be regarded as firmly established.[1]

The combination of peculiarities just mentioned at once characterises the skulls of Birds and Reptiles, and distinguishes them from all others.

In all these animals, the basi-occipital bone gives attachment to a pair of ex-occipitals, which articulate, above, with a distinct supra-occipital. The homology of these bones with those which have received similar names in the Man's and in the Pike's skull is not doubted; and, indeed, their relations to one another, and to the exits of the eighth pair, are so similar as to allow of no discussion on this point.

Furthermore, the skulls of all Reptiles and Birds are roofed in by membrane bones, the correspondence of which with the parietals and frontals of Man is universally admitted; and, in all, there is a single or a double vomer, clearly identifiable with that of the Man and that of the Fish. So, again, there is no doubt about the homology of the premaxillæ and the maxillæ, the palatine and the pterygoid bones with the parts so named

[1] The caution expressed in the text seems to be no longer necessary, as my friend Mr. Parker, who possesses a remarkably extensive knowledge of the details of the structure and development of the vertebrate cranium, informs me that he has now found "the median basi-sphenoid and the symmetrical basi-temporals in Ophidians, Anguians, Scincoids, Iguanians, Geckos, Chamæleons, Cyclodonts, Lacertians, Monitors, Chelonians, Crocodiles, and in all kinds of Birds." Mr. Parker agrees with my suggestion (*supra*, p. 173), that the basi-temporals of the *Sauropsida* (or Birds and Reptiles) are the homologues of the *lingulæ sphenoidales* of Man. He has found similar bones in numerous Mammals, and they are of especially large size in the Mole and in the Shrew. He informs me that the Sheep has no bony centre for the basi-sphenoid, the alisphenoids meeting in the middle line. Nevertheless its *lingulæ* are well developed at the commencement of the last third of intra-uterine life.

in Man. Nor is it questioned that the mandible and the hyoidean arches, in a general way, correspond with his. But there has been, and is, very great divergence of opinion as to the true nature of certain bones in the side walls of the skull, and of some of those which enter into the composition of the maxillary apparatus. I shall address myself chiefly to the discussion of these debatable ossifications.

The bone of most importance among these (the misinterpretation of which must needs, indeed, completely vitiate and render worthless any theory of the vertebrate skull) is that which lies in the side wall of the cranium, in front of the exoccipital; while it is connected below with the basi-sphenoid, and above with the supra-occipital and parietal. In all Birds and Reptiles the relations of this bone are essentially such as are shown in the accompanying figures of sections of the skulls of an Ostrich, a Crocodile, and a Turtle (Fig. 42, A, B, C). In all these it will be observed, that the aperture of the exit of the third division of the trigeminal (*V*) lies in front of a bone, which is notched, or perforated, by apertures for the *portio dura* and *portio mollis*, and that the anterior part of the organ of hearing is lodged within this bone. Furthermore, an external view of this region of the skull (Fig. 43, A and B) shows that the bone in question contributes, in each case, the anterior half of the boundary of the *fenestra ovalis*. In other words, the bone in question has every essential relation of that ossification which, in Man and in the Pike, I have termed *pro-otic*.[1]

The other elements of the periotic capsule are not far to seek. In the Turtle one of them retains its independence throughout life, and occupies a considerable space on the exterior of the skull, though, internally, only a small strip of it is seen in front of the foramen for the eighth pair (Fig. 42, C). This bone furnishes the posterior half of the frame for the *fenestra ovalis*, with so much of that of the *fenestra rotunda* as is osseous, and it

[1] This is the bone called by Cuvier "rocher," and regarded by him and by most of the German anatomists as the homologue of the *pars petrosa* of the human temporal bone. I took the same view myself when I delivered the Croonian Lecture in 1858, and I do not now *substantially* depart from it. For that part of the *pars petrosa* which is most obvious and visible in the interior of the skull is its pro-otic portion; and so long as the complex nature of the *pars petrosa* was unknown, the identification of the bone *Pr.O* in the Bird and Reptile with the petrosal of the Mammal was the nearest approximation that could be made to the truth. Cuvier's identification would have been absolutely correct if he had termed the ornithic and reptilian bone not "petrosal," but "anterior part of the petrosal."

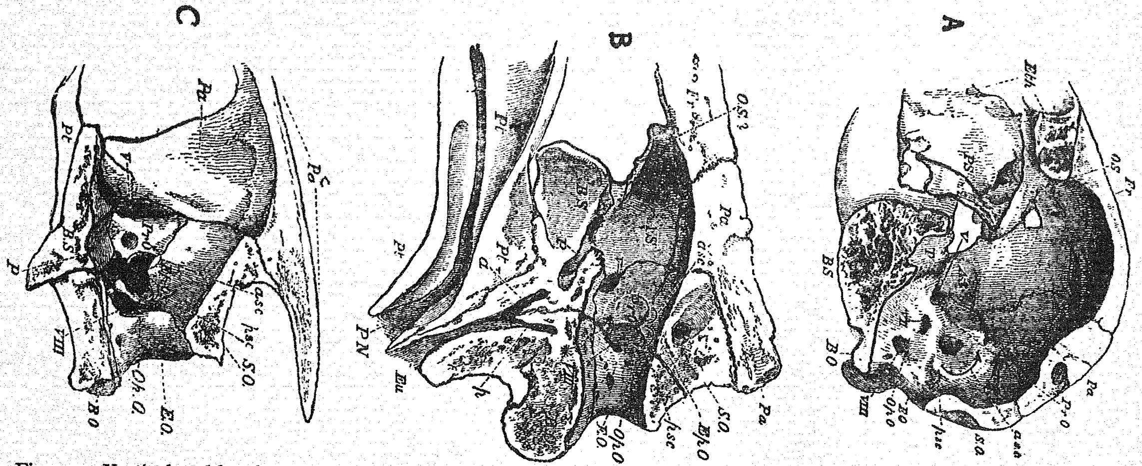


Fig. 42.—Vertical and longitudinal sections of the cranial chambers of (A) an Ostrich (*Struthio camelus*), (B) a Crocodile (*C. biporcatus*), and (C) a Turtle (*Chelone midas*), to show the interior of the cranial cavity of each. In B, * indicates the end of the cochlear plate of the opisthotic of the Crocodile; *Eu*, the common Eustachian tube, with *a* and *p* its anterior and posterior affluents; *P N*, the posterior nares. The arrows denote the position of the anterior and posterior vertical semicircular canals. In all the figures *P* indicates the pituitary fossa.

lodges the posterior and outer part of the auditory organ. It answers precisely, therefore, to the *opisthotic*.[1]

The corresponding ossification in most other Reptiles and in Birds early coalesces with the ex-occipital.

The third periotic bone, the *epiotic*, does not remain distinct throughout life in any Reptile or Bird, and its place appears to be taken by a triangular process of the supra-occipital, which shelters the summits of the vertical semicircular canals. But the study of development has shown that this part of the supra-occipital is, in many, if not all, Reptiles and Birds, developed from a separate centre, which subsequently coalesces with the supra-occipital; so that, just as the opisthotic in these animals ordinarily coalesces with the ex-occipital, the epiotic anchyloses with the supra-occipital.

In many Reptiles, though two of the three periotic bones coalesce with their neighbours, the suture between the three persists on the inner surface of the skull, and is always shaped like a Y (Fig. 42, B); the stem of the Y answering to that part of the suture which separates the pro-otic from the opisthotic ossifications, while the diverging branches of the Y correspond with the suture between the opiotic and pro-otic in front, and that between the epiotic and opisthotic behind. In the Turtle an interspace filled with cartilage takes the place of the stem of the Y (Fig. 42, C).

In the adult Crocodile the epiotic is united with the supra-occipital, and the opisthotic with the ex-occipital; but that process of the opisthotic (*c*, Fig. 43, A), which separates the *fenestra ovalis* from the *fenestra rotunda* (the anterior and inner edge of which, only, is completed by bone) where it meets the pro-otic below and anteriorly (at *d*, Fig. 43, A), sends downwards and backwards a process, which curves round the cochlea, and, expanding to a broad plate, adjusts itself by harmonia (at *b*) to the outer and lower edge of the opisthotic, and to part of the posterior edge of the pro-otic. The anterior and inferior angle of the broad plate is thicker than the rest, and is seen in the interior of the dry skull, at the bottom of the stem of the Y-shaped suture (* Fig. 42, B). If, as has been remarked, this

[1] Cuvier termed this bone the "*occipital externe*." Hallmann regarded it as the equivalent of the "mastoid," and I followed him in my Croonian Lecture. In the absence of a full knowledge of the development of the human *pars petrosa*, it was difficult, if not impossible, to see one's way to any better conclusion.

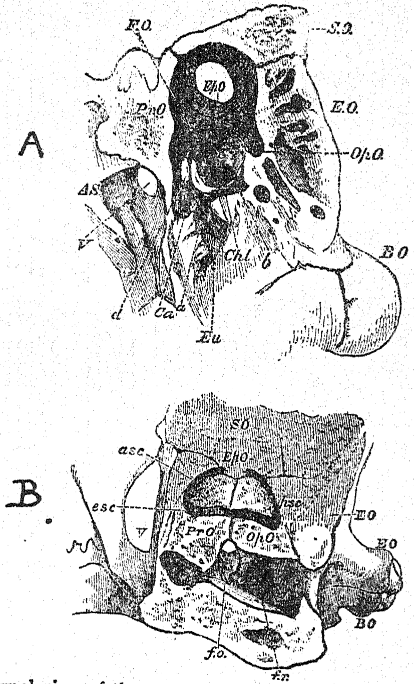


Fig. 43.—External view of the auditory region of the skull in (A) a Crocodile (*C. biporcatus*), and (B) a Turtle (*Chelone midas*). The walls of the tympanic cavity have been cut away in each case so far as is necessary to show the auditory *fenestræ;* and, in the Turtle's skull, the semicircular canals are also partially displayed. In the Crocodile's skull (A) *F.O.* is the *fenestra ovalis*, separated by the cochlear process of the opisthotic, *c*, from the *fenestra rotunda; Chl* is the hook formed by the curved process (*b*) of the opisthotic, which supports the cochlea externally. The lower end of the cochlea rests in the fossa *a*, formed by the basi-sphenoid and basi-occipital. The upper end, bounded externally only by cartilage, has disappeared in the dry skull and, with it, the outer lip of the *fenestra rotunda*, the plane of which is horizontal, and nearly on the level of the dotted line leading from *Op.O* in the figure. *d* is a small process of the pro-otic, against which the bend of the curved cochlear process (*b*) rests. The dotted line from *b* indicates the position of the suture between the hinder end of that process and the remainder of the opisthotic bone. *Ca*, the carotid canal; *Eu*, the upper opening of the posterior of the two canals by which each tympanum communicates with the common Eustachian tube. The narrow anterior tympanic canal opens just in front of *Ca*, the cleft-like aperture being traversed by the dotted line from *d*. In the Turtle's skull (B) *Op.O* is a distinct bone from *E.O*, and sends down a process between *f.o.*, the *fenestra ovalis*, and *f.r.*, the *fenestra rotunda*, which terminates in no recurrent hook, but otherwise corresponds exactly with the cochlear process (*c*) in the Crocodile.

part of the curved cochlear plate of the opisthotic be pressed upon with a point, it gives way; but this is not because it is merely suturally connected with the periotic bones, as has been supposed, but because the lamina of bone by which the cochlear plate is fixed to the opisthotic is very thin and elastic.

Among the many singular speculations which the historian of the theory of the skull will have to record, perhaps the

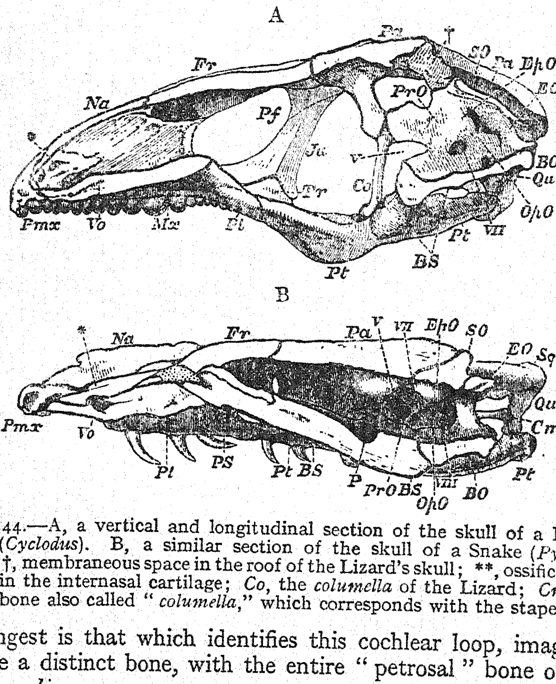


Fig. 44.—A, a vertical and longitudinal section of the skull of a Lizard (*Cyclodus*). B, a similar section of the skull of a Snake (*Python*). †, membraneous space in the roof of the Lizard's skull; **, ossifications in the internasal cartilage; *Co*, the *columella* of the Lizard; *Cm*, the bone also called "*columella*," which corresponds with the stapes.

strangest is that which identifies this cochlear loop, imagined to be a distinct bone, with the entire "petrosal" bone of the *Mammalia*.

In Birds, the three periotic bones anchylose with one another, as well as with the adjacent supra-occipital and ex-occipital, so completely that even the Y-shaped suture becomes obliterated (Fig. 42, A).

The determination of the homologues of the periotic bones in the skulls of Birds and Reptiles, and more especially of the

pro-otic, is not only a matter of first-rate importance in itself, but it involves that of certain other bones of the side walls of the skull.

In the *Chelonia*, and in many Lizards, the lateral walls of the cranium, between the pro-otics and the prefrontals, are entirely occupied by cartilage, or by membrane. In the dry skull of the Turtle (Fig. 42, C) it is true that there is an apparent bony wall in front of the pro-otic, but this is only a process, sent down from the parietal, which becomes connected with the pterygoid, and with a small, distinct lamella of bone.

In Lizards a distinct, rod-like bone (*Co*, Fig. 44, A, and Fig. 45), occupies a corresponding position, articulating above

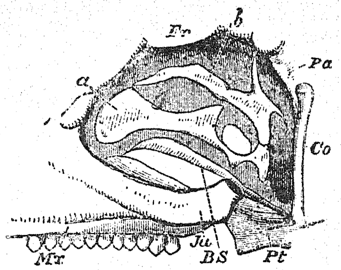


Fig. 45.—The inter-orbital septum of a Lizard (*Iguana*). *B S*, the anterior prolongation or beak of the basi-sphenoid; *a*, the inferior median ossification; *b*, the superior paired ossification of the left side of the inter-orbital septum; *Co*, the columella.

with the parietal, and below with the pterygoid, and receives the name of the *columella*.

In both Chelonians and Lizards the basi-craniai axis is laterally compressed in the presphenoidal region, and is converted into a vertical inter-orbital septum, as in the Pike. In the Chelonians, neither the septum, nor the membraneous, or cartilaginous, alisphenoidal and orbito-sphenoidal regions connected with it, present any ossifications, but, in many Lizards, delicate laminæ of bone are developed in this region. In the *Iguana tuberculata*, for example (Fig. 45), the inter-orbital septum is supported below by the prolonged beak of the basi-sphenoid. Above this, it presents a long median presphenoidal ossification (*a*) forked posteriorly. The forks are connected with two bones, one on each side (*b*), which appear to represent orbito-sphenoids.

The Crocodiles, on the other hand, possess a large and distinct lateral ossification in front of each pro-otic (*A S*, Fig. 42, B). This ossification bounds the foramen for the third division of the fifth nerve in front, and unites with the basi-sphenoid below and with the parietal above, so far agreeing with the ali-sphenoid. Since it extends so much further forward than the alisphenoid ordinarily does, Cuvier has suggested that it probably represents both the ali- and the orbito-sphenoids; but Stannius has pointed out the existence of two small ossifications close to the optic foramina, with an insignificant descending median stem at their bases. The former he considers to be the orbito-sphenoids and the latter the presphenoid.

In these Reptiles, in the *Lacertilia* and in the *Chelonia*, the *basis cranii*, as has been already stated, is modified anteriorly into an inter-orbital septum, as in the Pike; but in the *Ophidia*, the Cyprinoid, or Batrachian, type of skull reappears, and the cavity of the cranium is continued without any sudden narrowing, from above downwards, from its posterior to its anterior end. In the Ophidian skull (Fig. 44, B) the side walls of the cranium, in front of the pro-otics, are completely closed in by bones, which might readily be taken for alisphenoids and orbito-sphenoids; but, according to Rathke, they are merely downward growths of the parietals and frontals, and therefore can have nothing to do with the true lateral cranial elements.

The anterior part of the *basis cranii* in Birds is always vertically elongated into an inter-orbital septum, as in the *Crocodilia*, *Lacertilia*, and *Chelonia*. In the Ostrich (Fig. 42, A) the presphenoid is completely ossified, but, in other members of the class, the nature and extent of the presphenoidal ossifications may vary greatly. The alisphenoid is always well ossified, and occupies its characteristic position in front of the pro-otic and of the exit of the third division of the trigeminal nerve (Fig. 42, A). The orbito-sphenoids, on the other hand, may or may not be represented by bone. In the Ostrich they are present, and are continuous with the presphenoid.

Reptiles possess prefrontal and post-frontal bones, which usually remain distinct throughout life, and are admitted to be homologous with those of Fishes, and therefore the line of argument which identified the prefrontals of the Pike with the lateral masses of the ethmoid in the Man is equally applicable to the same bones in Reptiles. In Birds, the post-frontals have only a doubtful and exceptional distinctness, and in them the

true prefrontals seem early to coalesce with the ethmoid. The last-mentioned cranial element is usually ossified and appears upon the upper surface of the skull, in Birds; while, in *Reptilia*, it almost always remains cartilaginous. In the extinct *Dicyno-*

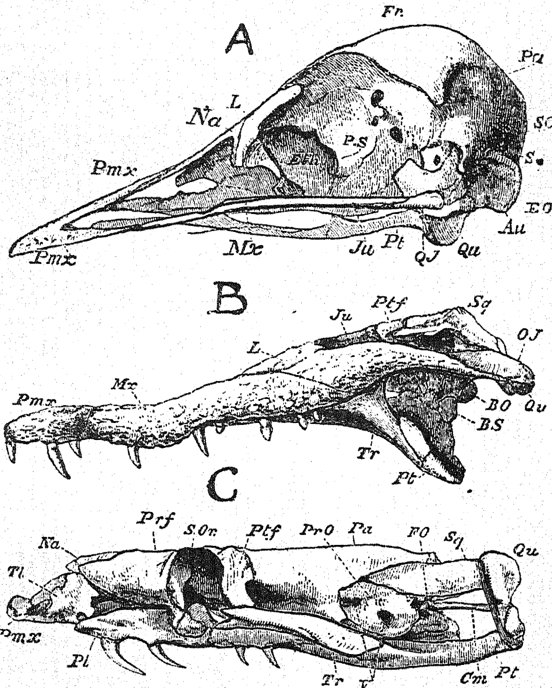


Fig. 46.—Lateral views of the skulls of (A) an Ostrich, (B) a Crocodile, and (C) a Python, without the mandible. In the Python's skull the maxilla has also been removed. *Tl*, turbinal bone of the Ophidian.

don, however, it and the presphenoidal region were completely ossified.

In Birds, in consequence of the prolongation of the snout into a beak, the internasal part of the basi-facial axis acquires a considerable size, and becomes the subject of a great variety of ossifications, which, in many Birds, are so arranged as to allow the anterior part of the cranio-facial axis to be movable on

its posterior part. In many Lizards, on the other hand, the anterior part of the cranium is rendered movable upon the posterior in another way. The cranio-facial axis in front of the basi-sphenoid is cartilaginous, and consequently slightly flexible, while the roof of the skull between the parietals, the supra-occipital and the periotic bones is merely membraneous (†, Fig. 44, A); hence, the front part of the skull is capable of being slightly raised or depressed, in a vertical plane, upon the posterior part.

Next to the pro-otic, the squamosal and the quadrate bones of Birds and Reptiles have been the subject of the greatest amount of controversy among morphologists.

The bone which was originally called "*os quadratum*" is that movable facial bone of the Bird (*Qu*, Fig. 46, A) which is articulated, above, with the outer side of the periotic capsule, and especially with the pro-otic bone, and below with the *os articulare* of the mandible, while, internally and anteriorly, it is connected with the pterygoid. In the *Crocodilia* (Fig. 46, B) and *Chelonia*, a bone, admitted by all to be the homologue of this, is attached immovably in the same region: in most *Lacertilia* (Fig. 47) it is movable, and remains connected with the produced extremity of the pro-otic bone; but, in most *Ophidia* (Fig. 42, C) its proximal end is thrust out from the skull upon the extremity of another bone. However, its homology with the quadrate of the Bird is not affected by this circumstance.

With what bone in the human skull does this correspond? Cuvier identified it with the tympanic of Man, and his interpretation has been generally accepted; but the tympanic is always a membrane bone, whereas this is always a cartilage bone. The tympanic directly supports the tympanic membrane, while this bone sometimes gives no direct attachment to the tympanic membrane at all. The tympanic of Mammals again becomes smallest in those *Mammalia* which most nearly approach Birds and Reptiles, and is never known to articulate, by a movable joint, with the *malleus*, which, as we have seen, is the representative of the *os articulare* of the mandible of the lower *Vertebrata*.

It is impossible, therefore, that the quadrate bone should be the homologue of the tympanic of *Mammalia*. On the other hand, it corresponds altogether with the quadrate bone of Fishes, which is united in like manner with the pterygoid arcade, and is similarly connected by a movable joint with the

articular pieces of the mandible; and this quadrate bone of Fishes is, I have endeavoured to show, the homologue of the incus of the *Mammalia*. I make no question that, as Reichert long ago asserted, the Bird's *os quadratum* and, therefore, that of the Reptile, is the equivalent of the Mammalian *incus*.

It is difficult to understand how any doubt can be entertained as to the bone which is the homologue of the Mammalian squamosal in Birds. Lying above the tympanic cavity, between the parietal, frontal, and periotic bones, is a membrane bone (*Sq*, Fig. 46, A) which corresponds with the Mammalian squamosal, and with no other bone in the Mammalian skull.

But if this be the Bird's squamosal, there is no difficulty in

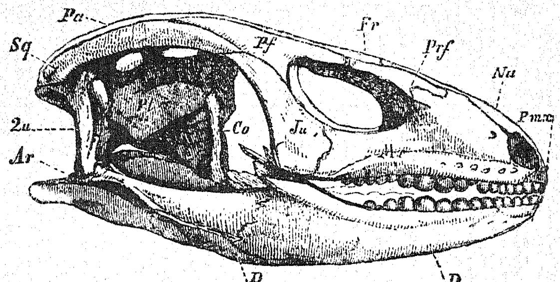


Fig. 47.—The skull of a Lizard (*Cyclodus*).—*D D*, Dentary piece of the lower jaw; *Qu*, Os quadratum; *Sq*, Squamosal.

determining that of any Reptile, the *Crocodilia*, *Lacertilia*, *Chelonia*, and *Ophidia* all presenting a bone in a similar position. It is this bone which, in most *Ophidia* (Fig. 46, C), carries the *quadratum* as on a lever; but, as Rathke has well shown, the final position of the *quadratum* is a result of developmental modification, the proximal end of that bone being originally in *Ophidia*, as in other Reptiles, applied to the periotic capsule.

The palato-maxillary apparatus presents a considerable diversity of structure in Reptiles and Birds. In all Birds, and in most Reptiles, the pterygoid and the quadrate bones are more or less closely connected, but in the Crocodiles and Chamæleons they are separated. In *Crocodiles* and *Chelonia*, and in the extinct *Plesiosauria*, the quadrate bone is immovably united with the skull, and the other facial bones are firmly and fixedly united with one another and with the cranium. In most Birds and *Lacertilia*, on the contrary, the quadrate bone is movably

articulated with the skull, and its motion may be communicated by the pterygoid, the quadrato-jugal and the jugal bones to the fore-part of the face. This mobility reaches its maximum, on the one hand, in such birds as the Parrots, in which the beak and fore-part of the basi-facial axis are united by a sort of hinge with the rest of the skull; and, on the other, in the Serpents, in which, as has been already stated, the quadrate bone is

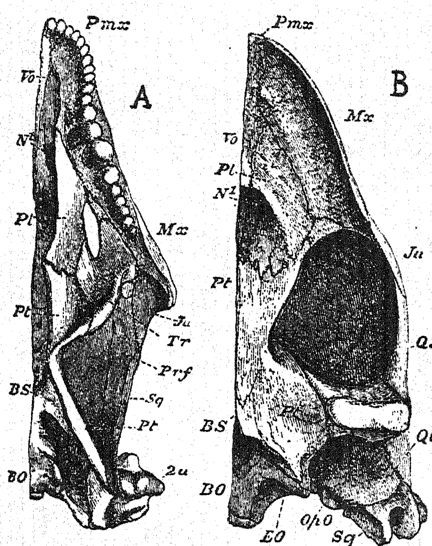


Fig. 48.—Views of one half of the palatine surface of the skull of, A, a Lizard (*Cyclodus*), and B, a Turtle (*Chelone midas*). N^1, the posterior nasal aperture.

shifted to the end of the squamosal, and the palatine, pterygoid, and maxillary bones are bound only by ligaments to the skull, so that the utmost possible amount of play is allowed to the bones which surround the mouth.

In many Reptiles a bone makes its appearance which cannot, at present, be identified with any bone of Fishes or of Mammals. This is the *transverse* bone of Cuvier (*Tr*), which unites together the maxilla with the palatine and the pterygoid.

Remarkable differences are noticeable in the degree to which

the premaxilla is developed in the various orders of Reptiles and in Birds. In the Snakes it is very small, or rudimentary; in the *Lacertilia*, *Chelonia*, and *Crocodilia* it has a moderate size; while in the extinct *Ichthyosauria*, and still more in Birds, the premaxilla attains vast dimensions, completely surpassing

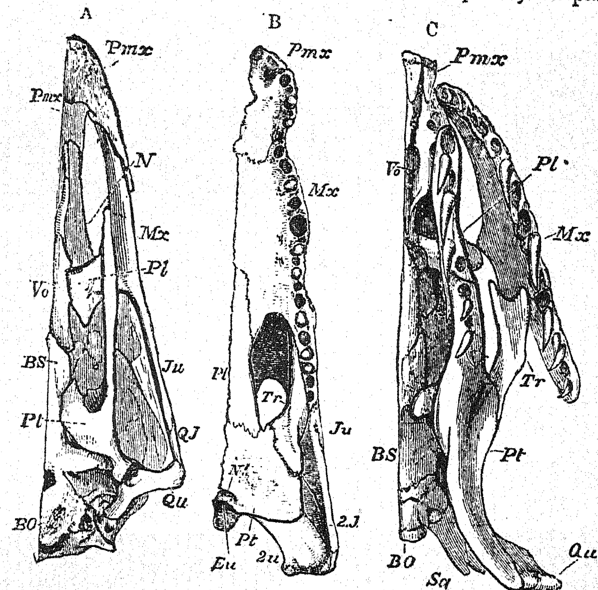


Fig. 49.—Views of one half of the palatine surface of the skull in (A) an Ostrich, (B) a Crocodile, (C) a Python. *N*, the posterior nasal aperture (median nares of Man) in the Bird. The dotted line traverses the posterior nasal aperture, situated between the palatine, the vomer, and the maxillary. The corresponding opening is placed between *Vo* and *Pl* in the Snake. N¹, the posterior nasal aperture, or posterior nares, of the Crocodile.

the maxillary element, which in Birds is reduced to a mere bar of bone, connected by similar slender rods, which represent the jugal and quadrato-jugal, with the outer part of the distal end of the quadrate bone.

In the *Ophidia*, most *Lacertilia*, and Birds, the nasal sacs open below and behind into the cavity of the mouth, by apertures placed between the vomer and palatine bones, which correspond

with what I have termed the "median nares" in Man; or there is, at most, an indication of a separation between the oral cavity and the nasal passage, produced by the sending downwards and inwards of a process by the maxillary and palatine bones on each side. But, in the *Crocodilia* (Fig. 49, B), not only the maxillary and palatine bones, as in Man, but the pterygoid bones, in addition, send such prolongations downwards and inwards; and these, meeting in the median line, shut off from the cavity of the mouth a nasal passage, which opens into the fauces by the posterior nares (N^1, Fig. 49). The arrangement of the palatine bones is such that, in most *Crocodilia*, the vomers are completely excluded from the roof of the mouth.

When a tympanic cavity exists in the branchiate *Vertebrata*, it is little more than a diverticulum of the buccal cavity, connected by so wide an aperture with the latter, that an Eustachian tube can hardly be said to exist. In the *Ophidia* and in certain *Lacertilia* the tympanic cavities and Eustachian tubes are altogether absent, and, even in the higher *Lacertilia*, the tympanum can hardly be said to have definite bony walls. In the *Chelonia*, on the other hand, the opisthotic and the pro-otic bones are produced outwards so as to form the anterior and posterior boundaries of a cavity, the *antivestibulum Bojani*—which is bounded externally by the great quadrate bone. The latter is funnel-shaped, and deeply notched posteriorly and inferiorly. The tympanic membrane is fixed to the margins of the funnel, and the so-called "*columella*," which answers to the *stapes*, is fastened by one end to this tympanic membrane, and traversing the notch and entering the *antivestibulum*, passes to its other insertion into the membrane of the *fenestra ovalis*. The Eustachian tubes have separate openings into the pharyngeal cavity, and curve upwards and backwards from the latter round the inferior and posterior edges of the quadrate bones to open into the tympana.

In Birds the tympanic cavity is roofed over by the squamosal, while a more or less complete floor is furnished to it by the basi-sphenoid, and a back wall by the produced ex-occipital (and opisthotic?). It may be completed in front by fibro-cartilage or even by bone, and the *membrana tympani* is fastened to the outer margin of these boundaries of the tympanum and not to the quadrate bone.

The Eustachian passages ordinarily traverse the basi-sphenoid, and when they reach the base of the skull unite into a single,

cartilaginous, common Eustachian tube, which opens in the middle line, on the roof of the mouth.

In the *Crocodilia* the tympanic cavities and Eustachian passages are still more remarkably disposed.[1]

The tympanic cavity of *Crocodilus biporcatus* (Fig. 43, A; Fig. 50) is distinguishable into an inner and an outer part. The

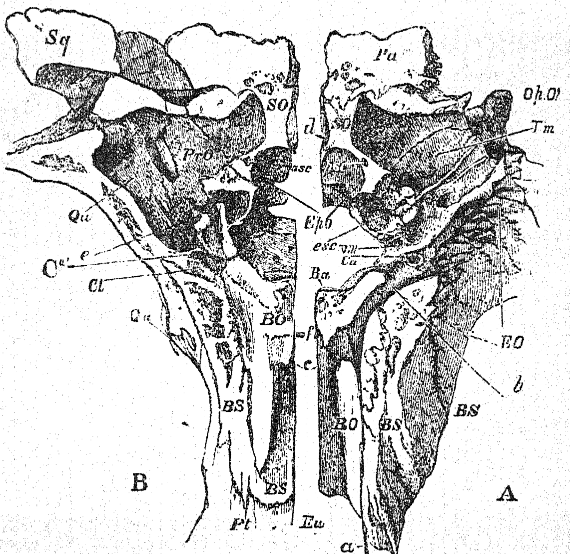


Fig. 50.—Vertical and transverse sections of the left tympanic cavity of *Crocodilus biporcatus*. A, posterior, B, anterior segment; *a*, bristle passed into the small lateral Eustachian passage leading from *b*, the posterior tympanic passage, which opens into *c*, the common Eustachian passage; *d*, a bristle thrust into the air-passage which traverses the supra-occipital; *f*, bristle passed into the anterior tympanic passage; *Ca*, *Ca*[1], carotid canal; *Cl*, fossa for the extremity of the cochlea; *Tm*, inner division of the tympanic cavity.

latter is bounded by the squamosal bone, above and behind, by the quadrate bone, below and in front. Into the former the supra-occipital enters, above; the quadrate, and, to a slight

[1] These were first carefully described by Professor Owen in a memoir published in the "Philosophical Transactions" for 1850. Windischmann, "De Penitiori auris in Amphibiis Structura" (1831), has given but a very imperfect account of them.

extent, the basi-occipital and basi-sphenoid below. To the posterior wall of the inner division, that outward and backward prolongation of the ex-occipital, which answers to the opisthotic of the turtle, contributes, while the front wall is formed partly by the quadrate and partly by the pro-otic bones.

Externally the tympanum opens by the external auditory meatus—its internal wall is formed chiefly by the pro-otic, opisthotic, and epiotic. The two latter are, as I have already stated, anchylosed, respectively, with the ex-occipital and the supra-occipital.

Each tympanic cavity communicates with its fellow of the opposite side, superiorly, by a wide passage, which perforates the supra-occipital bone and has a secondary diverticulum traversing the ex-occipital. Below, the tympana communicate with one another indirectly, by means of the common median Eustachian tube, the aperture of which, formed, half by the basi-sphenoid and half by the basi-occipital, is seen on the base of the skull behind the posterior nares (*c*). Each tympanum communicates with the common Eustachian tube by two passages: one, wide, from the posterior and inferior part of the tympanum (*b*); and one, very narrow, from its anterior and inferior region (*f*).

The two exits are separated by that part of the floor of the tympanum which is formed by the basi-sphenoid and basi-occipital. This presents, behind, a hemispherical fossa (*Cl*) into which both the basi-sphenoid and basi-occipital enter, and, in front, a round aperture with raised edges, situated altogether in the basi-sphenoid (*Ca*). The fossa lodges the distal blind end of the cochlea. The aperture leads into a canal, which, passing downwards and forwards in the basi-sphenoid, opens into the pituitary fossa, and lodges the internal carotid.

The upper aperture of the anterior, narrow, passage from the tympanum (*f*) is situated in front of the lip of the carotid canal, and, at first, lies between the basi-sphenoid and the pro-otic; but, soon turning inwards, it enters the basi-sphenoid, and passes beneath the carotid canal, to open into a much wider median channel. The latter ends blindly in front and above, behind and below the pituitary fossa; but, inferiorly, it traverses the substance of the basi-sphenoid, to open into the upper and front part of the common Eustachian tube (Fig. 50, B).

The posterior, wide, passage (*b*) leads downwards and inwards through the substance of the basi-occipital, and the two passages of the opposite tympana unite to form a short median canal,

which opens, on the front face of the basi-occipital, into the common Eustachian tube (Fig. 50, A).

The posterior tympanic passage has, however, another means of communication with the exterior; for, just before it joins with its fellow, it gives off, downwards, a narrow canal, which traverses the basi-occipital, and opens on its inferior face to the outer side of, and a little behind, the aperture of the common Eustachian tube (*a*, Fig. 50, A). There might, then, be said to be three Eustachian tubes in the Crocodile — two small and lateral, one for each tympanum, and one large and median, common to both tympana.

Where the posterior tympanic passage passes into the tympanum, the ex-occipital presents a round aperture with raised edges, which is the anterior termination of the posterior division of the canal for the internal carotid (C^a, Fig. 50, B). In the interval between this aperture of entrance and that of exit already described, the internal carotid is unprotected by bone, and is closely adherent to the outer surface of the cochlea; which, held by the cochlear hook already described, rests inferiorly upon the fossa afforded by the basi-sphenoid and basi-occipital (*Cl*).

The posterior wall of the tympanum also exhibits, internally, the aperture by which the eighth pair of nerves reaches the exterior; externally, those by which the portio dura leaves, and the external carotid enters; superiorly, between the supra-occipital and the squamosal, is a cleft which leads to the occipital surface in the dry skull.

The early stages of the development of the skull of a Bird have already been described. The process of formation of the Reptilian skull has been admirably worked out by Rathke in the Common Snake, *Coluber natrix*, and I conclude this Lecture by an abstract of his researches on this subject.[1]

The differences between the basis of the skull and the vertebral column in the earliest embryonic condition are,—

1. That round that part of the notochord which belongs to the head, more of the blastema, that is to be applied, in the spinal column, to the formation of the vertebræ and their different ligaments, is aggregated than around the rest of its extent, and—

2. That this mass grows out beyond the notochord to form the cranial trabeculæ.

The lateral trabeculæ, at their first appearance, formed two

[1] Entwickelungsgeschichte der Natter, 1839.

narrow and not very thick bands, which consisted of the same gelatinous substance as that which constituted the whole investment of the notochord, and were not sharply defined from the substance which lay between them and at their sides, but seemed only to be two thickened and somewhat more solid, or denser, parts of that half of the basis of the cranium, which lies under the anterior cerebral vesicle.

Posteriorly, at their origin, they were separated by only a small interval, equivalent to the breadth of the median trabecula, and thence swept in an arch to about the middle of their length, separating as they passed forwards; afterwards they converged, so that, at their extremities, they were separated by a very small space, or even came into contact. Altogether they formed, as it were, two horns, into which the investing mass of the notochord was continued forwards. The elongated space between them, moderately wide in the middle, was occupied by a layer of softer formative substance, which was very thin posteriorly, but somewhat thicker anteriorly. Upon this layer rested the infundibulum; and in front of it, partly on this layer, partly on the trabeculæ, that division of the brain whence the optic nerves proceed; and, further forwards, the hemispheres of the cerebrum. Anteriorly, both trabeculæ reached as far as the anterior end of the head, and here bent slightly upwards, so that they projected a little into the frontal wall of the head, their ends lying in front of the cerebrum. Almost at the end of each horn, however, I saw a small process, its immediate prolongation, pass outwards and form, as it were, the nucleus for a small lateral projection of the nasal process of the frontal wall.

The middle trabecula grows, with the brain, further and further into the cranial cavity; and as the dura mater begins to be now distinguishable, it becomes more readily obvious than before, that the middle trabecula raises up a transverse fold of it, which traverses the cranial cavity transversely.[1] The fold itself passes laterally into the cranial wall; it is highest in the middle, where it encloses the median trabecula, and becomes lower externally, where it forms, as it were, a short ala proceeding from the trabecula. With increasing elongation, the trabecula becomes broader and broader towards its free end, and, for a short time, its thickness increases. After this, however, it gradually becomes thinner, without any change in its

[1] What Rathke terms the "middle trabecula," appears to be only very indistinctly developed in Fishes and *Amphibia*.

tissue, till, at the end of the second period, it is only a thin lamella, and after a short time (in the third period) entirely disappears.

In Mammals, Birds, and Lizards, that is, in those animals in general in which the middle cerebral vesicle is very strongly bent up and forms a protuberance, while the base of the brain exhibits a deep fold between the infundibulum and the posterior cerebral vesicle, a similar part to this median trabecula of the skull is found.

In these animals, also, at a certain very early period of embryonic life, it elevates a fold of the dura mater which passes from one future petrous bone to the other, and after a certain time projects strongly into the cranial cavity. Somewhat later, however, it diminishes in height and thickness, as I have especially observed in embryos of the Pig and Fowl, until at last it disappears entirely in these higher animals also, the two layers of the fold which it had raised up coming into contact. When this had happened, the fold diminishes in height and eventually vanishes, almost completely.

The two lateral trabeculæ, which in the Snake help to form the anterior half of the basis of the skull, attain a greater solidity in the second period, acquire a greater distinctness from the surrounding parts, and assume a more determinate form, becoming, in fact, filiform; so that the further forward, the thinner they appear. They increase only very little in thickness, but far more in length, during the growth of the head. Altogether anteriorly, they coalesce with one another, forming a part which lies between the two olfactory organs and constitutes a septum. As soon as these organs increase markedly in size, this part is moderately elongated and thickened, without, however, becoming so dense as the hinder, longer part of the trabeculæ. The prolongations into the lateral projections of the nasal processes, which now proceed from the coalesced part in question, also become but little denser in texture for the present, though they elongate considerably.

The lateral parts and the upper wall of the cranium, with the exception of the auditory capsules, or of the subsequent bony labyrinth, remain merely membraneous up to the end of the second period; consisting, in fact, only of the cutaneous covering, the dura mater, and a little interposed blastema, which is hardly perceptible in the upper part, but increases in the lateral walls, towards the base of the skull.

The notochord reaches, in very young embryos of the Snake, to between the auditory capsules; and further than this point it can be traced neither in the Snake nor in other *Vertebrata*, at any period of life, as manifold investigations, conducted with especial reference to this point, have convinced me.

At the beginning of the third period, the basal plate chondrifies, at first leaving the space beneath the middle of the cerebellum membraneous; but this also eventually chondrifies, and is distinguished from the rest of the skull only by its thinness.

Lateral processes grow out from the basal cartilage just in front of the occipital foramen, and eventually almost meet above. They are the ex-occipitals.

The two lateral trabeculæ—parts which I have also seen in Frogs, Lizards, Birds, and Mammals—chondrify at the beginning of the third period. At first, they pass, distinct from one another throughout their whole length, as far as the frontal wall, on entering which they come into contact; they are more separate posteriorly than anteriorly, and they present, in their relative position and form, some similarity with the sides of a lyre. But as the eyes increase, become rounder, and project, opposite the middle of the trabeculæ, downwards towards the oral cavity, the latter are more and more pressed together, so that, even in the third period, they come to be almost parallel for the greater part of their length. Anteriorly, where they were already, at an earlier period, nearest to one another, they are also pressed together by the olfactory organs (which have developed at their sides to a considerable size), to such a degree that they come into contact for a great distance and then completely coalesce; they are now most remote posteriorly, where the pituitary body has passed between them,[1] so that they seem still to embrace it. Anteriorly, between the most anterior regions of the two nasal cavities, they diverge from their coalesced part, as two very short, thin processes, or cornua, directed upwards, and simply bent outwards.

It has been seen above that the median trabecula does not chondrify, but eventually disappears; in its place, a truly cartilaginous short thick band grows into the fold of dura mater from the cartilaginous basal plate.

Where the pituitary gland lies, there remains between the

[1] The pituitary body, however, as Rathke has since admitted, does not pass between the trabeculæ, and is developed in quite a different manner from that supposed in the memoir on *Coluber*.

lateral trabeculæ of the skull a considerable gap, which is only closed by the mucous membrane of the mouth and the dura mater. But there arises in front of this gap, between the two trabeculæ, as far as the point where they have already coalesced, a very narrow, moderately thick, and anteriorly pointed streak of blastema, which, shortly before the end of the third period, acquires a cartilaginous character and subsequently becomes the body of the presphenoid.

Altogether, anteriorly, however, where the two trabeculæ have coalesced, there grows out of this part, from the two cornua in which it ends, a pair of very delicate cartilaginous plates. At the end of the third period both plates acquire a not inconsiderable size, take the form of two irregularly-formed triangles, and are moderately convex above, concave below, so as to be, on the whole, shell-shaped. The nasal bones are developed upon these, while below them are the nasal cavities, and the nasal glands with their bony capsules.

The alæ, or lateral parts, of the two sphenoids do not grow, like the lateral parts of the occipital bone, out of the *basis cranii*, the foundation of which is formed by the cephalic part of the chorda, but are formed separately from it, although close to it, in the, until then, membraneous part of the walls of the cranium.

The alæ of the presphenoid (orbito-sphenoids), which are observable not very long before the termination of the third period, appear as two truly cartilaginous (though they never redden), irregular, oblong plates of moderate thickness; lie in front of the optic foramina, at the sides of the lateral trabeculæ of the skull; ascend from them upwards and outwards, and are somewhat convex on the side turned to the brain, somewhat concave on the other. The alæ magnæ (alisphenoids) are perceptible a little earlier than these. They are formed between the eye and the ear, and also originally consist of a colourless cartilaginous substance: they appear, at the end of the third period, as irregular four-sided plates; lie at both sides of the anterior half of the investing plate of the chorda; ascend less abruptly than the alæ orbitales, and are externally convex, internally concave.

The upper posterior angle of each elongates, very early, into a process, which grows for a certain distance backwards, along the upper edge of the auditory capsule, and applies itself closely thereto.

The auditory capsules, or the future petrous bones, chondrify,

as it would appear, the earliest of all parts of the skull: the *fenestra ovalis* arises in them by resorption.

The *ossification* of the Snake's skull commences in the basi-occipital, or, at any rate, this is one of the first parts to ossify. At a little distance from the occipital foramen, there arises a very small semilunar bony plate, the concave edge or excavation of which is directed forwards; thereupon, the bony substance shoots from this edge further and further forwards, until at length the bony plate has the form of the ace of hearts. Its base borders the fontanelle in the base of the skull, which lies under the anterior half of the third cerebral vesicle, while its point is contiguous to the occipital foramen; for the most part it is very thin, and only its axis (and next to this its whole posterior margin) is distinguished by a greater thickness. The cephalic part of the notochord can be recognised in the axis of this bony plate up to the following period. It passes from the posterior to the anterior end of the bony plate, where it is lost, and is so invested by the osseous substance of the plate that a small portion of the latter lies on the upper side of the notochord, a larger portion beneath it. On this account it forms, on the upper side of the plate, a longitudinal ridge, which subsequently becomes imperceptible by the aggregation of matter at the sides. On one occasion, however, I saw, in an embryo which had almost reached its full term, a similarly formed and sized bony cone, which, through almost its entire length, appeared merely to lie *on* the body of the basi-occipital, since it had only coalesced with it below.

The nucleus and sheath of the cephalic part of the notochord become gradually broken up and the last trace of them eradicated, as the ossification of the basi-occipital proceeds, like the nucleus and sheath of the rest of the notochord wherever a vertebral body is developed.[1]

The articular condyle is not yet formed. The ex-occipitals ossify through their whole length and breadth.

The body of the basi-sphenoid is formed between the above-mentioned posterior fontanelle of the *basis cranii* and the pituitary space, therefore far from the cephalic part of the notochord. It ossifies by two lateral centres, each of which forms

[1] In the Stickleback it has appeared to me that the wall of the anterior conical termination of the notochord in the *basis cranii* becomes ossified, or, at any rate, invested by an inseparable sheath of bony matter, just in the same way as the "urostyle" is developed in the tail.

a ring round the carotid canal.[1] The alisphenoids ossify in their whole length and breadth; the orbito-sphenoid only slightly, and the presphenoid not at all. The premaxillary bone arises as an azygos triangular cartilage between the cornua of the anterior ethmo-vomerine plate. It ossifies from a single centre.

The auditory capsule, or the future petrosal [=periotic] bone, may, even at the end of this period, be readily separated from the other part of the cranial wall, and still consists, for the most part, of cartilage. On the other hand, the triangular form, which it had before, is not inconsiderably altered, since it greatly elongates forwards, and thus, as it were, thrusts its anterior angle further and further forwards, and becomes more unequal-sided. At the lower edge, or the longer side of it, about opposite to the upper angle, at the beginning of this (third) period, or indeed somewhat earlier, a diverticulum of the auditory capsule begins to be formed (the rudimentary cochlea), and develops into a moderately long, blunt, and hollow appendage, the end of which is directed downwards, inwards and backwards, and also consists of cartilage. Close above, and somewhat behind this appendage, however, there appears, at about the same time, a small rounded depression, in which the upper end of the auditory ossicle eventually rests; and, somewhat later, an opening appears in this depression which corresponds with the *fenestra rotunda* of man. Very much later, namely, towards the end of this period, the auditory capsule begins to ossify. Ossification commences in a thin and moderately long, hook-like process, which is sent forwards and inwards from the lower hollow diverticulum of the cartilage, and unites with the basi-sphenoid. From this point it passes upwards and backwards, and, for the present, extends so far that, at the end of this period, besides that process, the diverticulum in question, and about the anterior third of the auditory capsule itself, are ossified.[2] Later than at the point indicated, an ossific centre appears at the posterior edge of the auditory capsule, where it abuts against the supra- and ex-occipitals, but extends from hence by no means so far forward as to meet that from the other point.[3] The middle, larger part of the auditory capsule, therefore, for the present, remains cartilaginous.

In the beginning of the fourth period, a third ossific centre[4]

[1] These are the "basi-temporals" of Mr. Parker.
[2] This is the pro-otic ossification.
[3] The opisthotic ossification.
[4] The epiotic ossification.

arises in the upper angle of the capsule, whereupon all three grow towards one another. But the mode of enlargement and coalescence of these bony nuclei is very remarkable. They do not unite with one another in such a manner as to form a continuous bony capsule for the membraneous part of the labyrinth, but are permanently separated by cartilagino-membraneous and very narrow symphyses. On the other hand, one [the epiotic] coalesces, in the most intimate manner, with that edge of the supra-occipital which is nearest to it; so that, even in the more advanced embryos, this bone and it form a moderately long oblong plate, each end of which constitutes a small, tolerably deep, and irregularly-formed shell, containing a part of the anterior, or upper, semicircular canal. The second bony centre [the opisthotic] becomes anchylosed with the anterior edge of the lateral part of the occipital bone, and also forms a small irregularly-shaped, but longish scale, which contains the deeper, or lower part, of the posterior crus of that semicircular canal, and besides this, the lower sac, or representative of the cochlea. The remaining bony mass developed in the auditory cartilage [the pro-otic], however, includes the greater part of the membraneous portion of the labyrinth, and is the largest. The same phenomenon, viz., that the petrosal bone breaks up, as it were, into three pieces, of which two coalesce with the occipital bone, occurs also in *Lacerta agilis*, and probably takes place in like manner, if we may conclude from the later condition of the petrous bone to the earlier, in *Crocodilia* and *Chelonia*.

It has been seen that subsequent observers have fully justified the conviction here expressed by Rathke.

VII. THE SKULLS OF MAMMALIA

We have met with no important difficulties in the way of identifying the bones of the Bird's skull with those found in the skulls of the *Reptilia* and still lower *Vertebrata*; and hence, if the cranium of a Mammal be compared with that of a Bird, the bones which correspond in the two will obviously be homologous throughout the series.

The accompanying figure represents a longitudinal and vertical section of the skull of a Beaver (*Castor fiber*), drawn of

the same absolute length as the section of the Ostrich's skull (Fig. 42, A), and exhibiting a corresponding extent of the cranium. The three segments of the basi-cranial axis are at once recognisable and identifiable with the basi-occipital, basi-sphenoid, and presphenoid of the Bird; but the basi-sphenoid is truncated at its anterior end, as in the Crocodile, not produced into a long beak, as in Birds and many Lizards. The occipital and supra-occipital bones, again, have all the relations of those of the Ostrich, and are universally admitted to be the homologues of the latter.

In the Ostrich, as we have seen (Fig. 42, A), there lies in front

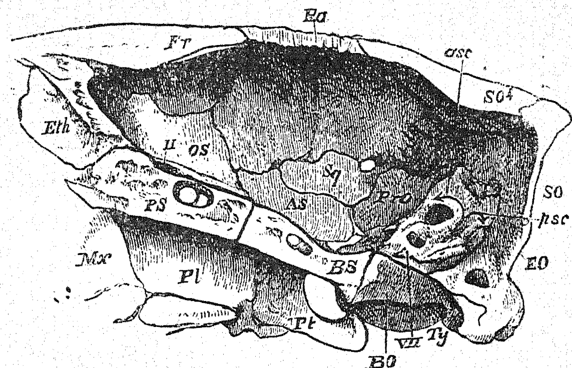


Fig. 51.—Longitudinal and vertical section of the cranial cavity of a Beaver.

of the ex-occipitals a large bony mass, composed of the confluent opisthotic, epiotic, and pro-otic bones. The inner face of the single periotic bone thus formed is divided into two surfaces, one anterior and one posterior, by a ridge which runs somewhat obliquely from above downwards and forwards. The anterior surface is concave, looks somewhat forwards, articulates in front with the alisphenoid, and contains no part of the organ of hearing; the third division of the trigeminal nerve passes out in front of it. The posterior surface presents, inferiorly, the apertures for the *portia dura* and the *portio mollis*; superiorly and in front, a fossa arched over by the anterior vertical semi-circular canal; while, superiorly and behind, it contains the posterior vertical semicircular canal. Between the posterior

edge of this division of the bone and the ex-occipital the eighth pair of nerves leaves the skull.

In the Beaver (Fig. 51), there is a single mass of bone not dissimilar in form and proportional size, which has always been admitted to be the homologue of the *pars petrosa* and *pars mastoidea* of Man, and the general relations and characters of which may be described in exactly the same terms. The inner face is divided into two surfaces, one anterior and one posterior, by a ridge which runs, somewhat obliquely, from above downwards and forwards. The anterior surface is concave, and looks slightly forwards; it articulates in front with a bone which, as all agree, corresponds with the alisphenoid of Man, and lies behind the exit of the third division of the trigeminal. The posterior division presents, inferiorly, the apertures for the *portio dura* and *portio mollis*; superiorly and in front, a fossa arched over by the anterior vertical semicircular canal; while superiorly and behind it contains the posterior vertical semicircular canal. Between the hinder edge of this division and the ex-occipital, the eighth pair of nerves leaves the skull.

The inferior, or internal, edge of the periotic bone in the Bird, and that of the *pars petrosa* in the Beaver, comes into relation with the basi-occipital and basi-sphenoid; externally, each exhibits the *fenestra ovalis* and *rotunda*, and is related, above, to the squamosal.

In fact, the only noteworthy differences between the ornithic periotic, and the Mammalian *pars petrosa* and *mastoidea*, are that the former becomes anchylosed with the adjacent bones of the cranial wall, while the latter remain separate from them, and that, while the periotic articulates, above, with the parietal in the Bird, the corresponding ossification in the Mammal is separated from that bone by the squamosal.

On the former distinction it would of course be absurd to lay any weight; as regards the latter, it is deprived of all significance by the circumstances that in some Birds—as, *e.g.*, the common Fowl—the squamosal interposes between the periotic and the parietal in the wall of the skull; and that in some Mammals—as, *e.g.*, the Sheep—the squamosal is completely excluded from the skull, and the *pars petrosa* unites with the parietal.

The simple anatomical comparison of the parts appears, then, to be amply sufficient to demonstrate that the *pars petrosa* and *mastoidea* of the Beaver correspond in every essential respect

with the periotic mass of the Bird, and therefore with the pro-otic, opisthotic, and epiotic bones of Reptiles and Fishes. On the other hand, no one has ever doubted that the petrosal and mastoid of the Beaver answer to the petrosal and mastoid of Man; and therefore we are led by the comparison of adult structure, merely, to exactly the same conclusion as that at which we arrived by the study of development, to wit, that the *pars petrosa* and *pars mastoidea* of Man answer to the periotic bones of the lower Vertebrates.

In front of the periotic, the side wall of the cranium is formed by an alisphenoid, anchylosed below with the basi-sphenoid; and, still more anteriorly, by a large orbito-sphenoid, united

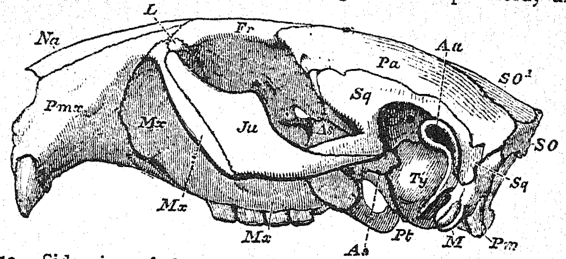


Fig. 52.—Side view of the skull of a Beaver. *Ty*, tympanic bone; *M*, *pars mastoidea*; *Pm*, the downward process of the ex-occipital, called "paramastoid."

inferiorly with the presphenoid, which is distinct from the basi-sphenoid behind, and from the ethmoid in front.

In the roof of the skull (Fig. 52) a large inter-parietal, SO^1, which corresponds with the upper part of the *squama occipitis* of Man, occupies an interval left, posteriorly, between the two parietals; otherwise, the bones correspond with those found in the roof of the skull of the Bird. The ethmoid, the vomer, the nasal bones, the premaxillæ, maxillæ, lachrymal, jugal, and squamosal bones, the palatines, and the pterygoids of the Rodent, present no difficulties to the student acquainted with the structure of the Bird's and Reptile's skull; but he will miss the pre-frontals, the post-frontals, the quadrato-jugal, the transverse, and the quadrate bones, together with all the pieces of the lower jaw, save the dentary.

The post-frontals, the quadrato-jugal, the transverse, and four out of the five missing pieces of each ramus of the lower jaw, appear to have no representatives in the Mammalian skull.

The pre-frontals, on the other hand, are represented by the so-called "lateral masses of the ethmoid," with their developments, the superior and middle ethmoidal turbinal bones, which answer precisely to those of Man. A third turbinal, developed from the primitive cartilaginous wall of the olfactory chamber, eventually becomes united with the maxilla, and answers to the inferior or maxillary turbinal of Man; while, in the Beaver, there is a fourth turbinal, connected with the superior turbinal and with the nasal bones, which may be termed the "nasal turbinal."

How far these well-defined turbinals of the Mammal answer to the cartilaginous and osseous turbinals of Birds and Reptiles, is a question which has yet to be elucidated.

I have already endeavoured to show that the quadrate and articular bones of the oviparous *Vertebrata* are represented by the *incus* and *malleus* of Man, and consequently by the corresponding bones in all *Mammalia;* and that, as a consequence of the appropriation of two bones of the mandibular series to the uses of the organ of hearing, the dentary bone develops its own condyle, and articulates with the squamosal.

Another bone which appears to have no distinct representative in most oviparous Vertebrates [1] is very conspicuous in most Mammals, and far more so in the Beaver than in Man. This is the tympanic element, and it will be useful to study with especial attention the characters of this bone, its relations to the periotic, and the manner in which both are connected with the other bones of the skull.

In a transverse section of the conjoined tympanic and periotic bones, taken through the canal which is common to the anterior and posterior vertical semicircular canals (Fig. 53), the periotic mass is seen to be prolonged, external to and below the horizontal semicircular canal and that for the passage of the *portio dura,* into a stout "mastoid process" (*M*), which appears upon the outer surface of the skull, between the ex-occipital, the squamosal, and the tympanic, as a production downwards and outwards of the "*pars mastoidea,*" which is doubtless, as in Man, composed partly of the pro-otic and partly of the epiotic and opisthotic bones.

The tympanic bone is produced, externally, into a spout-like tube, directed forwards and upwards, which is the external auditory meatus (*Au,* Fig. 52); below and internally the tube

[1] I learn from Mr. Parker that all Birds above the *Struthionidæ* have a more or less perfect chain of tympanic bones, of which there are six in *Corvus corone.*

dilates into a thin walled hemispherical *bulla* (*b*, *c*, Fig. 53), open superiorly, and produced in front and anteriorly into a perforated process, which contains the osseous part of the Eustachian tube. The outer lip of the *bulla* and the auditory meatus are anchylosed with that region of the pro-otic which corresponds with the *tegmen tympani* in Man. The inner lip of the tympanic *bulla* is, as is the case with the corresponding edge of the tympanic bone of Man, applied against the opisthotic, but it does not anchylose with this bone in the Beaver; at any rate, for the greater part of its extent. Consequently, a very narrow cleft or fissure, leading into the tympanum, is opened up, if the inner lip of the *bulla* is gently prized away from the periotic mass in this region. I shall term this the "*tympano-periotic fissure*." The great difference between the tympanic bone of Man and that of the Beaver arises from the circumstance, that, in Man, by far the greater part of the bone is occupied by the external auditory meatus; the interval between the groove for the attachment of the tympanic membrane and the inner edge of the tympanic bone —which forms the floor of the tympanum—being quite insignificant, except in the region of the Eustachian tube. In the Beaver, on the other hand, this part of the tympanic bone is greatly enlarged, and constitutes more than the inner half of the *bulla tympani*.

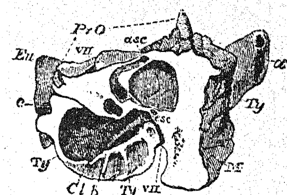


Fig. 53.—A vertical section of the conjoined tympanic and periotic bones of the Beaver (*Castor fiber*). *a*, external auditory meatus; *b*, groove for the tympanic membrane; *c*, the inner lip of the tympanic; *Eu*, Eustachian tube; *Cl*, cochlea; *M*, *pars mastoidea*.

The tympanic bone and the periotic being thus anchylosed together externally (though only coadjusted internally), form one bone in the adult Beaver. But this "*tympano-periotic bone*" is not anchylosed with any of the adjacent bones, even the squamosal remaining perfectly distinct. Nor, indeed, is it fixed to them by very firmly interlocking sutures, so that in the dry skull it may be pushed out without difficulty. It is held in place, in fact, only by the descending post-auditory process of the squamosal (answering to the posterior part of the *margo tympanicus*), which curves behind the external auditory passage; and by the fitting in of the "*pars mastoidea*" between the ex-occipital and supra-occipital.

Of the vast multitude of modifications undergone by the Mammalian skull, I select for comment, in this place, only a few of the most important, such as, firstly, those which are the result of unusual forms or combinations of bones in skulls not otherwise abnormal. Secondly, Those which are exhibited by the skulls of the higher Mammals as compared with the lower. Thirdly, Those which are presented by what may be termed aberrant Mammalian skulls, *e.g.*, the crania of the *Monotremata* and *Proboscidia*, and of the aquatic *Mammalia*—the *Sirenia*, *Phocidæ* and *Cetacea*.

I am not aware that there is any example among the *Mammalia* of the bones of the roof, or lateral walls, of the two posterior segments of the skull taking a share in the formation of the floor of the cranial cavity. On the other hand, a careful study of development will probably show that it is no uncommon circumstance for the orbito-sphenoids to unite together in the middle line, so as to exclude the presphenoid from the cranial floor, or even to supply its place entirely.

A still more remarkable deviation from the typical arrangement than this occurs in certain Mammals, and has been thus noted by Cuvier (Leçons ii. p. 319):—"La lame cribleuse de l'ethmoide dans tous les *Makis*, dans les *Loris*, et les *Galagos*, vient toucher comme dans l'homme, au sphénoide antérieur; tandisque, dans les Singes, elle en reste éloignée en arrière par le rapprochement des deux côtés du frontal."

I find the union of the frontals to which Cuvier refers in this passage to take place in *Cynocephalus*, *Macacus*, *Cercopithecus*, and *Semnopithecus*. The frontals, however, do not really separate the presphenoid and ethmoid, but only form, above the junction of these two bones, the front part of a thick osseous bridge, the hinder part of which is contributed by the orbito-sphenoids.

The Gorilla agrees with the Monkeys and Baboons in these respects. Thus, in the adult male Gorilla in the Museum of the Royal College of Surgeons, the distance from the anterior boundary of the *sella turcica* to the anterior end of the cribriform plate of the ethmoid is 1.4 in. Of this extent of the base of the skull, 0.35 in. is occupied by the conjoined orbito-sphenoids, 0.42 in. by the coalesced frontals, and 0.6 in. by the *lamina perpendicularis* of the ethmoid. But, in a vertical section, the ethmoid is seen to extend back under the basi-cranial processes of the frontals (which are not more than one-fifth of an inch

thick) as far as the suture between the orbito-sphenoids and these processes, which end anteriorly in a free rounded, transversely concave ridge, constituting the posterior boundary of the olfactory fossa. Laterally, the basi-cranial processes of the frontals arch downwards for a short distance and unite with the lateral masses of the ethmoid.

In the Gorilla, the frontal bridge is much smaller than in the lower Catarhines. The Chimpanzee approaches Man still more nearly; a triangular process of the presphenoid interposing itself between the frontals and joining the ethmoid. Sometimes, however, very small processes of the frontals just unite over this junction. In the Orang, the frontals are widely separated, as in Man.

The epiotic, pro-otic, and opisthotic bones are always anchylosed into a single periotic bone in the *Mammalia;* but they unite with the other elements of the temporal bone, and with the adjacent cranial bones, in very various modes, and the tympanic cavity presents very different boundary walls in different Mammals.

In the Beaver, as we have seen, the tympanic and periotic bones are anchylosed into a single "*tympano-periotic*," which remains unanchylosed with the squamosal, and is easily detached. In the *Sirenia* and in *Cetacea* (sooner or later) the same anchylosis takes place, but the tympano-periotic is still less firmly fixed in its place, and, in some *Cetacea*, does not appear at all in the interior of the skull, in consequence of the growth of the adjacent bones towards one another over it.

The tympano-periotic of the Rhinoceros, Horse, and Sheep, long remains unanchylosed to the surrounding bones, but is so wedged in between them as to be practically fixed within the walls of the skull.

In *Echidna* and in *Orycteropus* the periotic, the squamosal, and the tympanic remain perfectly distinct for a long time, if not throughout life.

The squamosal and tympanic of the Pig anchylose into a single "*squamoso-tympanic*," which is firmly fixed to the adjacent bones; but the periotic remains free, and consequently readily falls not *out of*, but *into* the skull.

In the nine-banded Armadillo (*Praopus*) it is the periotic and squamosal which are anchylosed, the tympanic remaining

rudimentary and free; and the Opossums and the Tapir exhibit a similar arrangement.

Other *Mammalia*, such as the *Carnivora* and *Primates*, have the squamosal, tympanic, and periotic all anchylosed together into one "*temporal bone.*"

Even in one and the same order the constitution of the tympanic cavity exhibits the most remarkable differences. To take the *Edentata* as an example:—

In the *Orycteropus* the walls of the tympanic cavity have a wonderfully reptilian arrangement; the periotic is very large in proportion to the other bones of the skull, and its plane presents comparatively little inclination, so that its exterior face looks more outwards than downwards. A large part of its posterior and outer face is seen, as a *pars mastoidea*, upon the exterior of the skull, between the supra-occipital, the ex-occipital, and the squamosal, but there is no distinct "mastoid process;" below, the periotic comes into contact with the basi-occipital and basisphenoid; in front, with the alisphenoid. The latter bone is strongly convex outwards, so as to present a posterior, as well as an external, face; the posterior face forms the front wall of the tympanum, and exhibits a somewhat deep excavation, or alisphenoidal air-cell.

The squamosal, a very large bone, is divided by a well-marked ridge into an upper face, which constitutes part of the roof, and an outer face, which forms a portion of the lateral wall, of the skull. The latter enters into the outer and upper wall of the tympanum; the former, very thin, constitutes the roof of that cavity, abutting internally upon the supra-occipital and parietal. The Fallopian canal is open for the greater part of its extent, and a hook-like osseous process, which overhangs its outer and posterior part, gives attachment to the hyoid.

The tympanic is a strong hoop of bone, incomplete above, and much shorter anteriorly than posteriorly. By its expanded anterior end it articulates by an interlocking suture with the squamosal. The thin posterior end is free.

In *Myrmecophaga tetradactyla* (and essentially the same arrangement obtains in the great Ant-eater), the squamosal, as in *Orycteropus*, enters largely into the wall of the cranial cavity; but the tympanic, which is large and bullate, is anchylosed with it. The tympanic, however, forms only the outer part of the posterior wall of the tympanum, the inner and posterior walls of that cavity being furnished by a downward process of the basi-

occipital, while its inner and anterior wall is formed partly by the pterygoid and partly by the alisphenoid. These two bones enclose a great air-cell, which communicates freely with the tympanic cavity behind. In front, it is closed by a thin bony partition, which separates it from a second large air-chamber, enclosed, partly by the alisphenoid and pterygoid, and partly by the palatine.

In the genus *Manis* there is a large *bulla*, formed altogether by the tympanic, which, in moderately young skulls, at any rate, is not anchylosed with the adjacent bones.

The squamosal is an immense bone, extending from the ex-occipital to the orbito-sphenoid, and entering into the lateral walls of the skull for that extent. Its posterior part, dilated and convex outwards, contains a large air-cell, which opens into the roof of the tympanum by a wide aperture. The plane of the periotic is nearly horizontal. It is a relatively small bone, and only a small part of it appears on the base of the skull, behind the tympanic *bulla*, the squamosal completely hiding it externally.

Of the Armadillos, some, like *Euphractus*, have a tympanic *bulla* of the ordinary construction, with, occasionally, a very long external auditory meatus; while others, such as the nine-banded Armadillos (*Praopus* of Burmeister), have a mere hoop of bone open above, almost as rudimentary as that of *Echidna*.

Or, if we turn to the perissodactyle *Ungulata* :—

In the *Rhinoceros*, the periotic and tympanic early anchylose together, but remain distinct from the surrounding bones, the compound tympano-periotic being only wedged in between the squamosal, ex-occipital, and other adjacent cranial bones, in such a manner that it cannot fall out. The "*pars mastoidea*" is completely hidden, externally, by the union of the squamosal and the paramastoid process of the ex-occipital over it. The region itself, however, is very well developed, and is continuous, internally and below, with a very strong, conical, somewhat curved, styloid process, to the flattened, free base of which the hyoidean apparatus is attached.

The tympanic element is very singularly formed. It has the shape of a very irregular hoop, open above and behind, and much thicker at its anterior superior than at its posterior superior end. The former, irregular and prismatic, is anchylosed with the periotic, just behind and above the auditory labyrinth; it then splits into two divisions, an anterior and inner and a posterior and outer. The anterior, acquiring a thick and spongy

texture, curves round to form the front part of the wall of the tympanum, and then ends in a free, backwardly-directed apex, without becoming in any way connected with the periotic, or with the posterior division. The latter, much thinner and denser, curves downwards and backwards in the same way, and also remains perfectly free, but its hinder end is prolonged into a flat process, which bends for a short way round the base of the styloid process. The outer wall of the tympanum is therefore very incomplete in the dry skull, opening forwards and downwards, first, by the fissure between the anterior branch of the tympanic and the periotic; and, secondly, by the cleft between the two divisions of the tympanic.

Posteriorly, there is a large irregular aperture between the hinder end of the anterior branch of the tympanic and the periotic. Externally, there is no bony auditory meatus—or rather the merest rudiment of one.

The Horse presents a very different structure. There is a tympano-periotic bone which is wedged in between the squamosal and adjacent bones, and not anchylosed therewith; but the *pars mastoidea* appears largely on the outside of the skull between the post-auditory process of the squamosal and the paramastoid, and the tympanic element consists of a complete *bulla*, with a long external auditory meatus. The styloid process is almost completely infolded by a vaginal process furnished by the auditory meatus, and the tympanic is altogether anchylosed to the periotic, posteriorly.

No Tapir's skull which I have examined has presented any trace of an ossified tympanic bone.[1]

In the Horse, most *Primates*, Carnivores and Rodents, the tympano-periotic fissure is closed, either by the close apposition, or by the actual anchylosis, of the inner lip of the tympanic to the periotic.

But, in the Sheep and Pig, this fissure is replaced by a wide elongated aperture, the inner edge of the tympanic *bulla* being rolled in like a scroll. In the Seals and *Cetacea* the scroll-like form of the immensely thick tympanic *bulla* becomes still more marked, and the tympano-periotic fissure wider; while the latter is converted into a great gap in the floor of the tympanum in *Orycteropus* and in the *Sirenia*, the tympanic being reduced to a mere thick hoop.

[1] According to Cuvier, " L'os de la caisse ne paroit jamais bien se souder avec les os voisins et tombe aisément, comme dans l'hérisson, le sarigue," etc

In many *Marsupialia* the alisphenoid dilates posteriorly and inferiorly into a funnel-shaped, thin-walled, bony chamber, which closes the tympanic cavity anteriorly, uniting by its edges with the tympanic bone. In certain *Insectivora*, such as the Hedgehog and Tenrec, the tympanic cavity is partly walled in by a process of the basi-sphenoid.

In *Hyrax*, and in many *Marsupialia* and Rodents, the jugal enters into the composition of the glenoid facet for the lower jaw. In the Marsupials the alisphenoid may also contribute towards the formation of this articular surface. In almost all Marsupials the angle of the mandible is continued inwards into a horizontal plate of bone. This "inflexion of the angle of the jaw" is peculiar to these Mammals.

The palatine and pterygoid bones present very considerable differences in their connections among *Mammalia*.

Thus, in the *Ornithorhynchus*, in the larger *Myrmecophagæ*, and in some *Cetacea*, the pterygoids unite in the middle line below, so as to prolong the bony palate beyond the palatines, as in the Crocodiles. In the Marsupials, on the other hand, the bony palate, formed only by the maxillæ and palatines, is often defectively ossified, so that large open spaces are left therein on the dry skull.

In order to understand the changes which the normal type of skull undergoes in the Mammalian series, it is necessary to define a few lines and planes by the help of certain well-marked organic fixed points.

A line drawn from the hinder extremity of the basi-occipital to the uppermost part of the junction between the presphenoid and the ethmoid, may be called the line of the axis of the *basis cranii*, or the "*basi-cranial line.*"

A second line, drawn from the premaxilla to the *basis cranii* through the junction of the vomer with the ethmoid, traverses the axis of the facial part of the skull, and may be termed the line of the axis of the *basis faciei*, or "*basi-facial line.*" This line, if produced upwards and backwards, will cut the foregoing so as to form an angle open downwards, which I shall term the "*cranio-facial angle.*"

A third line, drawn from the end of the basi-occipital bone to the posterior edge of the supra-occipital in the median line, will give the general direction of the plane of the occipital

foramen, or the *occipital plane*. The angle it forms with the basi-cranial line is the "*occipital angle*."

A fourth line, drawn from the *torcular Herophili*, or junction of the lateral and longitudinal sinuses, through the middle of a plane joining the tentorial edges of the pro-otic bones, will give the general direction of the tentorium, or, in other words, of the demarcation between cerebrum and cerebellum.[1] This line, therefore, may be taken to indicate the "*tentorial plane*." The angle it forms with the basi-cranial line is the "*tentorial angle*."

A fifth line, drawn through the median junctions of the cribriform plate of the ethmoid, with the frontal above and anteriorly, and with the presphenoid below and posteriorly, will give, in the same general way, the "*olfactory plane*." The angle it forms with the basi-cranial line is the "*olfactory angle*."

Lastly, the longest antero-posterior measurement of the cavity which lodges the cerebrum will give the "*cerebral length*."

Having defined these lines and planes, the following general rules may be laid down:—

1. The lower *Mammalia* have the *basi-cranial line* longer in proportion to the *cerebral length* than the higher. Taking the length of the *basi-cranial line* as 100, I have observed the *cerebral length* to be, in a well-developed European skull, 266; in a Negro, 236; in an adult female Chimpanzee, 180; in an adult male Gorilla, 170; in a Baboon, 144; in a Lemur, 119; in a Dog, 87; in a Beaver, 70; in a *Thylacinus*, 60; in an Opossum, 93; in *Echidna*, 100.

2. In the lower *Mammalia* the olfactory, tentorial, and occipital angles nearly approach right angles; or, in other words, the corresponding planes are nearly vertical, while they become more and more obtuse in the higher Mammals, until, in Man, these planes are nearly horizontal, in the ordinary position of the skull.

3. In the lower *Mammalia* (Fig. 54) the cranio-facial angle is so open as to reach 150° or more, but, in the higher *Mammalia*, it becomes smaller and smaller, until, in Man, it may be as little as 90°.

4. In many of the lower *Mammalia*, a sudden narrowing of the front part of the cranial cavity indicates the boundary between the chamber which lodges the cerebral hemispheres and that which contains the olfactory lobes of the brain (Fig. 54),

[1] Of course no straight line can give this boundary with exactness, as the co-adapted surfaces of the cerebrum and cerebellum, and consequently of the interposed tentorium, are curved in all directions.

and the latter cavity forms a large and distinct *olfactory fossa*. In the higher Mammals this cavity becomes absolutely and relatively smaller, until in Man it is so shallow and insignificant as to be hardly noticeable.

5. In many lower *Mammalia* the olfactory fossa is altogether in front of the cerebral cavity, and the cerebellar fossa is altogether behind it, the three being separated by marked constrictions (Fig. 54).

In the higher Mammals, on the other hand, the excessive development of the cerebral hemispheres causes the cerebral chamber to overlap the olfactory fossa in front and the cerebellar

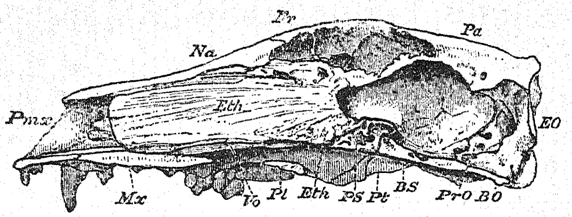


Fig. 54.—Longitudinal and vertical section of the skull of *Thylacinus cynocephalus*.

fossa behind; so that these come to be placed respectively under, instead of in front and behind, the cerebral chamber.

Thus it may be said, that in passing from the lower to the higher forms of Mammalian skull, we find the cavity for the cerebrum enlarging in proportion to the basi-cranial axis, and thrusting the olfactory plane downwards and forwards, the tentorial and occipital planes downwards and backwards, in such a manner that these may be said to rotate on the ends of the basi-cranial axis; at the same time, the basi-facial line rotates on the basi-cranial line, being more and more bent downwards and backwards.

It must be clearly understood that I by no means intend to suggest that all Mammalian skulls can be arranged in a series, the lower members of which shall be distinguished from the higher by always exhibiting smaller olfactory and occipital angles, larger cranio-facial angles, less proportional cerebral lengths, etc. On the contrary, the various angles and measurements show a considerable range of irrelative variation; as, for example, in the *Cetacea*, a relatively large cerebral length is associated with

small occipital and olfactory angles, and a very large cranio-facial angle; in the *Edentata* and *Monotremata* a somewhat large olfactory angle is associated with a small tentorial and occipital angle; and in the Opossum and *Echidna* the cerebral length is anomalously great. All that can be said is, that the crania of the higher orders of Mammals, as a whole, are distinguished from those of the lower orders by the characters I have mentioned.

The skull of *Echidna* (Figs. 55 and 56) may be taken as an

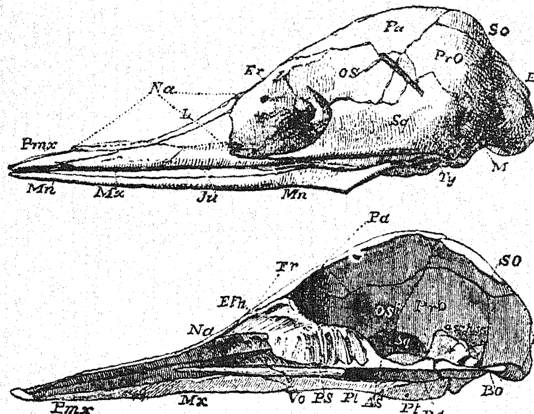


Fig. 55.—The skull of a young *Echidna* viewed from without, and in longitudinal and vertical section.

example of the "aberrant" monotreme type of skull. It is composed of a pyriform cranium proper, and a produced, beak-like maxillary portion. The lower jaw is remarkable for its length and slenderness, and the very small vertical height of its rami (Fig. 55).

The basi-occipital (*B.O.*) is very wide, and so much depressed as to be quite a thin lamella of bone; it contributes, to a small extent, to each occipital condyle, which, like the ex-occipital bone itself, is very large. The ex-occipitals are connected above by a wide supra-occipital, which extends so far upon the roof of the skull that the lambdoidal suture is not very distant from its summit. The plane of the roof of the skull slopes upwards and forwards, from the occipital foramen to this point.

The large parietals, anchylosed together in the middle line, form all but a very small portion of the rest of the roof of the skull, and are succeeded by the small frontals. These are met in the middle line, inferiorly, by the *lamina perpendicularis* of the ethmoid, which separates one olfactory chamber from the other, and are united by sutures, anteriorly, with the long nasals. These stop short of the anterior nasal aperture, being excluded therefrom by the premaxillaries.

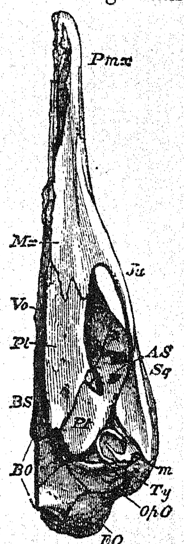


Fig. 56.—Under view of the left half of the skull of *Echidna*.

In the base of the skull the basi-sphenoid, presphenoid, and ethmoid are anchylosed together. The basi-sphenoid is a wide, flattened bone, somewhat deflexed at the sides. Its long, thin, postero-lateral margins articulate externally with the broad, flat bones (*Pt*) which contribute above to form the floor of the cranial cavity by filling up a vacuity which would otherwise exist between the basi-sphenoid, periotic, and ali-sphenoid. The thick posterior and external edges of these bones are excavated by a deep groove, which forms the front wall of the tympanum and of the Eustachian tubes. The palatine bones are completely anchylosed with the sphenoid, and pass abruptly inwards from the outer edges of that bone (Fig. 56). The anterior and internal edges of the bones (*Pt*), which obviously represent the pterygoids, articulate with them as well as with the basi-sphenoid. The anterior and external edges of the pterygoids are united with an antero-lateral prolongation of the pro-otic part of the periotic; and, rather above the cleft between the latter and the pterygoid, is fixed the large process of the malleus (*m*, Fig. 56), to which the tympanic ring closely adheres.

The periotic bone is remarkable for the lamellar prolongations which it sends forwards from its pro-otic, epiotic, and opisthotic regions, beyond the space required for the auditory organ, and which enter more largely into the side walls of the skull than any of its ordinary constituents. The periotic contributes towards the floor of the skull by a triangular process, which it sends in between the basi-occipital and the basi-sphenoid.

Posteriorly, it articulates largely with the ex-occipital, the foramen for the eighth pair being situated between it and the latter. By its wide superior prolongation it unites behind with the ex-occipital, posteriorly and superiorly with the supra-occipital; anteriorly and superiorly, first with the parietal, and then with a large bone (*OS*, Fig. 55) which stretches outwards, upwards, and backwards from the presphenoid and ethmoid, articulating partly with the frontal, and more extensively with the parietal. Except in its unusual articulation with the periotic, this bone corresponds with the orbito-sphenoid. Between the superior prolongation of the periotic, and its thin and imperfectly-ossified anterior and inferior prolongation, there is an interspace filled up by the squamosal. The lower edge of this prolongation articulates with the pterygoid, and, in front of this, forms the upper boundary of the foramen for the third division of the fifth nerve. Between its front edge and a small process, sent up by the palatine towards the orbito-sphenoid, is a small plate of bone, which alone seems to represent the alisphenoid.

The premaxillæ enter largely into the composition of both the upper and under regions of the snout. As has been already stated, they unite in front of the nasal bones, so as to exclude the latter from the anterior nares, as is the case in some *Crocodilia*. The maxillary bones send horizontally inwards a broad and long palatine process. This, like the corresponding process of the palatine bone, is separated from its fellow in the middle line, for some distance, by the vomer. On the left side of the specimen from which this description is taken there is a distinct large triangular lachrymal (Fig. 55); it is imperforate, and situated altogether upon the side of the face. An oblique suture extends downwards and forwards from that which separates this lachrymal, inferiorly, from the adjacent bones, and seems to mark off the jugal from the maxillary bone. On the right side neither this suture exists, nor any indication of a distinct lachrymal.

The essential characters of the Proboscidean cranium are best displayed in the fœtal Elephant, as the sutures become obliterated, and the true form of the skull is disguised by the enormous development of the air-chambers between the tables of the skull, in the adult.

Fig. 57 represents the longitudinally and vertically bisected skull of such an Elephant. The whole basi-cranial axis is

slightly concave upwards. The basi-occipital and the basi-sphenoid, the presphenoid, and the ethmoid are already so completely anchylosed that the traces of their primitive distinctness have almost disappeared. On the other hand, the presphenoid and the basi-sphenoid are widely separated by the remains of synchondrosis. The occipital angle is about 90°, the olfactory angle 160° to 170°.

The frontals enter as much into the front wall as into the roof of the skull, and extend largely down upon its sides. Anteriorly and externally they are prolonged into great arched supra-orbital processes, which form the roofs of the orbits.

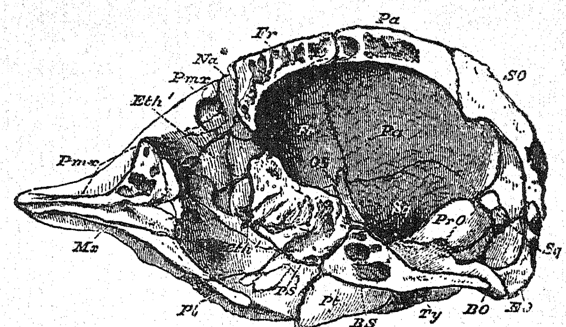


Fig. 57.—Longitudinally and vertically bisected cranium of a fœtal Elephant (*Elephas Indicus*).

The parietals are narrower in the middle line of the vertex than anywhere else, being encroached upon by the frontals, anteriorly, and by the supra-occipital behind. Infero-laterally, the parietals widen out very much and extend far down into the temporal fossæ, where they unite, in front, with the apices of the tolerably large orbito-sphenoids, and behind, with the periotic and supra-occipital. Below the inferior margin of the parietals the squamosals appear largely in the lateral wall of the skull.

The alisphenoids are very small, and are directed horizontally outwards. The foramen for the exit of the third division of the trigeminal is between the hinder margin of the bone and the periotic.

The latter bone has a considerable proportional size, and is devoid of any cerebellar fossa.

On the exterior of the skull the squamosal joins the ex-occipital

so that no "*pars mastoidea*" appears upon the surface. The post-glenoidal and post-auditory processes of the squamosal are very large, and bend towards one another inferiorly, so as to meet (in the adult skull) and form a spurious external auditory meatus.

But besides this, there is a true external auditory meatus which is, as usual, an outgrowth from the tympanic. The latter bone is very large and bullate. It is grooved anteriorly by the carotid, and the short styloid process appears between it, the squamosal, and the ex-occipital.

The tympanic and the periotic are anchylosed together and

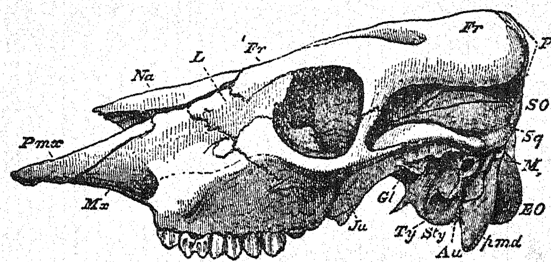


Fig. 58.—Side view of the skull of a Calf.—*pmd*, the paramastoid process of the ex-occipital.

wedged into the space left between the ex-occipital, squamosal, parietal, alisphenoid, and the basi-cranial axis.

The very short nasal bones (absent in the specimen figured) are adjusted by a broad posterior face to the frontals at *Na**. The large premaxillaries ascend along the sides of the anterior nasal aperture to the nasal bones, but are almost excluded from the palate, inferiorly, by the maxillaries; their alveolar portion, however, is very large and long, and this circumstance, together with the shortness of the nasal bones, throws the anterior nares, in the dry skull, almost to the top of the head. As the palatine processes of the maxillaries and palatines are, at the same time, relatively short, the posterior nares are situated but little behind the anterior nares, and thus the axis of the nasal passage forms a large angle with the basi-cranial axis. The lachrymal is a very small, though distinct, bone.

In the fœtal Elephant here described the space between the two tables of the skull is moderate, and is filled with a spongy

diplöe; but, with advancing age, the interspace between the tables in the frontal, parietal, and supra-occipital increases until it equals or exceeds the depth of the cranial cavity, and the diplöe is replaced by vertical plates and pillars of bone, between which air-cavities extend back from the frontal sinuses and nasal passages. The skull of the Elephant resembles that of the pig in many of its most important and characteristic features, and, through the Pig, its affinities are traceable to the other *Ungulata*. Of these, the skull of the Tapir resembles it most in some respects, such as the shortness of the nasal bones and of the palate; the consequent large angle which the axis of the nasal passages makes with the basi-cranial axis; and the prolongation downwards and forwards of the frontal bones.

On the other hand, some Ruminants carry to an extreme the development of the frontal into a great supra-orbital arch, its extension backwards in the middle line, and the concomitant expansion of the supra-occipital forwards; so that the parietals of the Ox, for example, are reduced to a comparatively narrow band in the middle line, while they expand widely in the temporal fossæ (Fig. 58).

The crania of the purely aquatic Mammals, such as the typical Seals, the *Sirenia* and the *Cetacea*, exhibit a certain similarity of character in the midst of very wide and important differences.

The basi-cranial axis is either flat or slightly curved upwards at its anterior and posterior extremities. The olfactory and occipital planes are vertical, or nearly so. The *squama occipitis*, alone, or united with large inter-parietal elements, extends upon the vertex of the skull between the parietals, and approaches, or even reaches, the frontals, so that the parietals are very much shorter antero-posteriorly than at the sides and below.

The frontals take but a small share in the formation of the roof of the cranial cavity; the nasals are relatively short, the anterior nasal aperture relatively large, and the posterior often situated far forwards. The prefrontals, or lateral masses of the ethmoid are small or rudimentary. The tympanic and periotic are always anchylosed together, and, whether connected or not with the squamosal, are more easily detachable from the skull than usual.

The Seals are extreme aquatic modifications of the carnivorous type of cranial structure; the *Sirenia*, of the ungulate type. The *Cetacea* present resemblances to both.

In the common Seal (*Phoca vitulina*) (Fig. 59) the cranial cavity is exceedingly broad and spacious, and the cerebral extends far further back over the cerebellar chamber, and is much larger in proportion to it, than is usual in *Carnivora*. There is a strong bony tentorium, and an osseous falx is more or less developed. The basi-cranial axis, very thin and broad, is curved, so as to be concave from before backwards. The synchondrosis between the presphenoid and basi-sphenoid persists. The superior and middle turbinal bones are greatly flattened from side to side, and unite below and internally with the *lamina perpendicularis*, or proper ethmoid, so that all direct communication with the superior and middle meatuses of the nose is shut

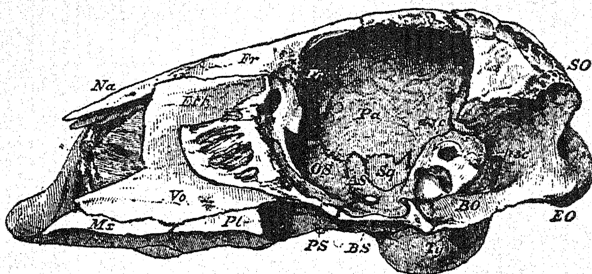


Fig. 59.—Longitudinal and vertical section of the skull of a Seal (*Phoca vitulina*). The premaxilla is absent.

off below. The inferior turbinal, on the other hand, is exceedingly large and complex in its structure. The orbito-sphenoids are large and, ascending upon the front wall of the skull, unite anteriorly behind and below the cribriform plate, so as to hide nearly the half of the ethmoid when the base of the skull is regarded from above. The presphenoid is relatively small.

Less than half the length of the frontal bones enters into the upper wall of the cranial cavity, the rest being devoted to the roof of the nasal chambers. This part of the frontals is very much narrower than the other, and is bent down at the sides, so as to form two broad thin plates, which wall in the superior and middle spongy bones, articulate below with the vomer and with the palatine, and take the place of the *os planum*.

The lower edge of the parietal unites with the front part of the alisphenoid and with the ex-occipital, leaving a great infero-

lateral space, which is filled up in front and above by the squamosal, and behind and below by the periotic. The squamosal is relatively a small bone, but the periotic and the tympanic, which are anchylosed with it, are very large. A swollen *pars mastoidea* appears on the exterior of the skull, and is hollowed internally by a cavity which opens into the cranium, and extends under the anterior and posterior vertical semi-circular canals.

The tympanic forms a very thick *bulla*, prolonged externally into an auditory meatus. It is firmly anchylosed with the prootic regions of the periotic and with the squamosal, but for the rest of its extent it is only applied to, and not anchylosed with, the periotic. It is pierced by the carotid canal.

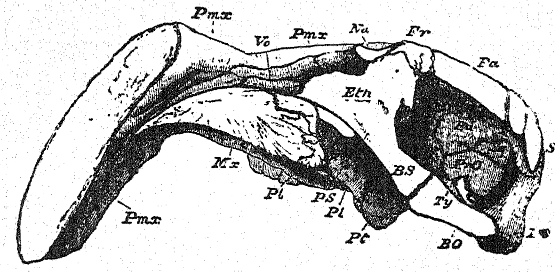


Fig. 60—Longitudinal and vertical section of the skull of a Dugong (*Halicore Indicus*).

The anchylosed squamosal, periotic, and tympanic are very easily detached from the walls of the skull, as is the premaxilla from the upper jaw.

The skull of the Dugong (*Halicore*, Fig. 60) presents the peculiarities of the cranial conformation of Mammals of the order *Sirenia* in a very marked form. The basi-cranial axis is almost flat above, but very thick. The suture between the basi-occipital and the basi-sphenoid persists, but that between the basi-sphenoid and the presphenoid is completely obliterated, as is that between the presphenoid and the ethmoid, which last has the form of a stout bony plate, with an almost vertical posterior edge, or *crista galli*. The upper median part of the frontals is very narrow from before backwards, so that they cover

not more than the posterior half of the upper edge of the ethmoid, and appear but very little on the roof of the cranial cavity; laterally and below, they are much expanded, and produced forwards and outwards. The greater part of the roof of the skull is furnished by the parietals, the longest antero-posterior diameter of which bones is in the middle line, as they are not separated, posteriorly, by the supra-occipital, or, anteriorly, by the frontals.

The orbito-sphenoids are large, and enter into the composition of the front wall of the skull. The alisphenoids are also large, and contribute to the formation of the side walls, as well as of the base, of the skull.

The squamosal appears in the interior of the cranium between the parietal, supra-occipital, and periotic, with which last it is not anchylosed.

The periotic, a large and dense ossification, has a very peculiar form, being divided into an inner portion, corresponding with the *pars petrosa*, and an outer thick mass which answers to the *tegmen tympani* and *pars mastoidea*.

The tympanic is a mere ring of bone, open above, and having a thicker anterior than posterior crus. It is by the former that it is more especially attached to the periotic, though the hinder, thinner crus also becomes anchylosed with that bone.

The squamosal unites behind and below with the ex-occipital, but leaves a space, superiorly, in which the *pars mastoidea* appears on the exterior of the skull. The malar process of the squamosal is exceedingly thick, and extends far forwards as well as transversely outwards. The frontals send very large processes downwards and forwards, as in the Elephant and Tapir, which are not only met by the maxillæ, as in the latter animal, but also meet, and indeed are covered by, the nasal processes of the premaxillæ. The lachrymals are large, but imperforate. The jugals, thick and curved, are connected with them.

The very small nasal bones are fixed by the greater part of their under surfaces to the anterior half of the ethmoid, beyond which they project but little, so that almost the whole of the vast anterior nasal aperture is, in the skeleton, uncovered. The premaxillæ are enormous, and constitute a large proportion of the lateral margins of the upper jaw as well as the whole of its anterior region. Their ascending, or nasal, processes are produced forwards instead of downwards, so that the point which corresponds with the *spina nasalis anterior* in Man is

nearly on a level with the top of the head. The alveolar process is even more largely developed, to contain the incisor tusks of the animal.

The maxillæ, also large and prolonged forwards, have very thick and long palatine processes, separated by a wide incisive foramen from the premaxilla. The palatine process of the palatine is also very thick, but it is shorter than deep, so that the posterior nares, which open behind it, are placed vertically under the hinder part of the anterior nares, in the dry skull. The vomer, thick and stout behind, thin and ridge-like in front and above, embraces the lower edge of the ethmoid, and is suturally united to both the palatines and the maxillaries.

The skulls of the *Sirenia* have resemblances on the one side with those of the ungulate Mammals and *Proboscidea;* on the other, with those of the *Cetacea,* but yet differ in many and most important respects from all.

The skulls of the *Cetacea* present more singular modifications than those of any other *Mammalia.* In all these animals, the basi-cranial axis is concave superiorly, and the primitive separation between the basi-sphenoid and presphenoid persists for a long time.

The vomer is very long, and extends backwards on the base of the skull at least as far as the basi-sphenoid, and sometimes covers the whole length of that bone.

The ethmoid has its posterior edge perpendicular, or nearly so, to the basi-cranial axis, and the foramina for the exit of the olfactory nerve are small or obliterated.

The frontals enter but very little into the roof of the skull, largely into its anterior and lateral walls. They are prolonged outwards and forwards into the long and broad supra-orbital processes, which are concave inferiorly, where they form the roof of the orbital cavity.

The parietals hardly appear at all, externally, upon the top of the skull, their median parts being obscured or interrupted by the inter-parietal and supra-occipital. They occupy a large space, however, in the temporal fossæ.

The ex-occipitals and supra-occipitals are enormous. The latter, usually increased by coalescence with the large inter-parietal, extend up to, or beyond, the vertex to meet the frontals. The orbito-sphenoid and alisphenoid vary in size. The squamosal is large, and is firmly fixed to the side of the skull, forming

part of the wall of the cranial cavity. The periotic, usually anchylosed into one bone with the bullate tympanic, sometimes

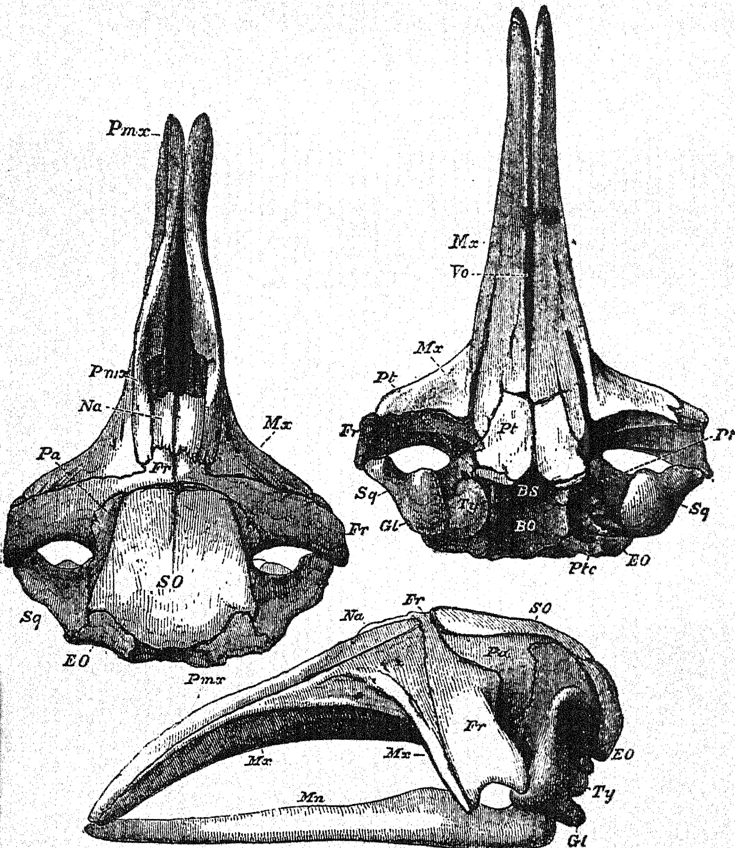


Fig. 61.—Upper, under, and side views of the skull of a fœtal Whalebone Whale (*Balæna australis*). The jugal bones are absent. In the under view the palatine bone is accidentally marked *Pt* instead of *Pl*.

enters largely into the wall of the cranium, sometimes is almost altogether excluded therefrom by the parietal, alisphenoid, and other adjacent bones, which send prolongations over it.

The maxillary apparatus is greatly elongated, so as to form a kind of beak. The premaxillæ enter into the upper and inner part of the whole length of this maxillary beak, but contribute little or nothing to its palatine surface and lateral boundaries, which are formed mainly by the maxillæ. The latter bones are always prolonged over, or in front of, the supra-orbital processes of the frontals.

The imperforate lachrymal is small, and sometimes coalesces with the jugal.

The nasal bones are always short, sometimes rudimentary; and the palatine bones are so disposed that the posterior nares are situated almost vertically under the anterior nares.

The squamosal bones are produced outwards, and the processes thus formed approach, or come into contact with, the posterior part of the supra-orbital processes of the frontals, which they separate from the jugal. Inferiorly, these processes support the glenoidal facets for the condyle of the lower jaw.

The sides of the broad basi-occipital are always prolonged downwards into free plates, which are concave outwards. These plates join the pterygoids in front, and the ex-occipitals behind, and so constitute the inner and posterior walls of an auditory chamber, the anterior and outer boundaries of which are furnished by the alisphenoid and the squamosal. In this chamber the tympano-periotic is lodged, sometimes quite loosely, at others fixed firmly in by interlocking sutures.

In the *Balænoidea*, or "Whalebone Whales," the symmetry of the skull is undisturbed, though there may be a slight inequality of the maxillæ. The skull of the fœtal *Balæna australis*, represented in Fig. 61, is perfectly symmetrical. Each lateral edge of the broad and flat basi-occipital is prolonged downwards and outwards into a broad process, concave outwards and convex inwards, the inferior edge of which is free, while the hinder edge unites with the ex-occipital, and the front edge with the pterygoid, to form the inner wall of the funnel-shaped chamber which lodges the tympano-periotic bone.

In front, this chamber is bounded by the pterygoid and the squamosal, and between and above them, for a small space, by the alisphenoid; behind, it is constituted almost entirely by the ex-occipital, while, externally and above, it is bounded and roofed in by the squamosal. Between these bones there is left, at the apex of the chamber, a considerable irregular aperture, which communicates with the cranial cavity.

The anterior and outer part of the under-surface of the squamosal is produced downwards into a great trihedral pillar, the obliquely truncated inferior face of which bears the articular surface for the mandible (*Gl*, Fig. 61). Behind this the squamosal presents a comparatively low wedge-shaped ridge (*a*, Fig. 62), between which and the "trihedral pillar" is a groove; while behind it, or between it and the ex-occipital, there is a deeper and wider transverse channel.

The periotic bone is irregularly triangular; the apex of the triangle, turned inwards and forwards, is thick and rounded, the anterior, posterior, and outer edges being thinner and more or

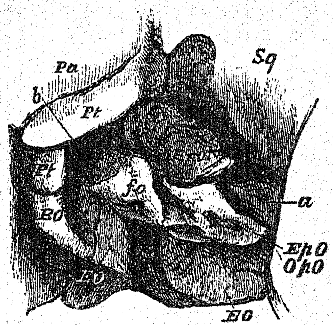


Fig. 62.—Enlarged view of the chamber which lodges the left tympano-periotic bone of the fœtal *Balæna australis.*—*a*, the "wedge-shaped ridge" of the squamosal; *C*, the aperture which leads into the interior of the skull; *f.o*, *fenestra rotunda.*

less irregular. The upper smooth and concavo-convex surface of the periotic adjusts itself to the under-surface of the squamosal where it forms the roof of the funnel-shaped cavity. The apex of the periotic, however, projects beyond this, and incompletely divides the irregular aperture above mentioned (*b*, Fig. 62) into an anterior division, which corresponds with the *foramen ovale* and *foramen lacerum medium*, and a posterior which answers to a *foramen lacerum posterius.*

The under-surface of the periotic, much more irregular, is divisible into three regions: an outer anterior; an outer posterior; an internal. The first and second are separated by a deep triangular notch in the outer margin of the bone, into which the inner end of the wedge-shaped ridge of the squamosal

is received. The first, broad and short (*PrO*), presents a rough surface in front, with which the tympanic articulates, and eventually anchyloses; and behind, a concave surface, which, entering into the roof of the tympanic cavity, answers to the *tegmen tympani*. The second, narrower, elongated, and prismatic, fits into the transverse channel behind the wedge-shaped

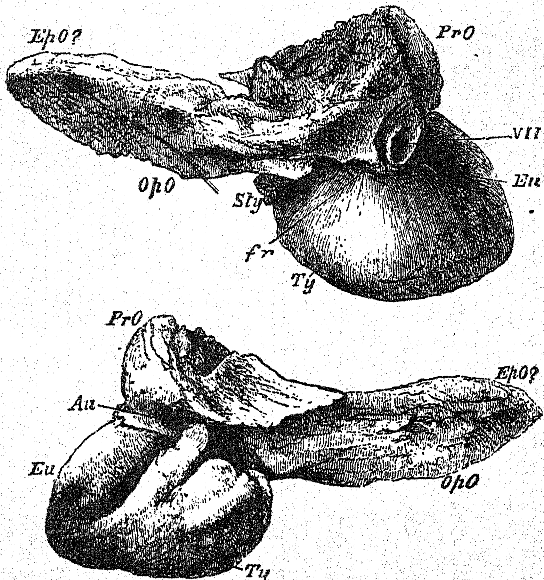


Fig. 63.—" Ear bones " of the adult *Balæna australis*. The upper figure gives the view from within; the lower, from without.

process (*a*). It corresponds with the *pars mastoidea*, and its rough outer extremity appears on the exterior of the skull, between the squamosal and ex-occipital.

The internal division, convex and rounded below, is formed by the pro-otic and opisthotic, and presents a large promontory with the *fenestra rotunda* (*f.o*) on its posterior surface, while the *fenestra ovalis* and Fallopian canal are visible upon its exterior. The tympanic bone (Fig. 63, *Ty*) is large, and scroll-like in form, very thick internally and below, and thin above and externally, where it presents the aperture of the external audi-

tory meatus. It is by this thin upper and outer edge only, that it eventually anchyloses with the *tegmen tympani* and *pars mastoidea*, and hence, as its substance is very dense and brittle, readily breaks off.

In the adult Whale the *tegmen tympani* and *pars mastoidea* become greatly elongated and very rugged, the tympanic also acquiring a very large size (Fig. 63).

The vomer is a very long and large bone, deeply grooved above for the ethmoidal cartilage, which extends downwards and forwards between the premaxillæ and the maxillæ to near the anterior end of the snout. Its expanded upper and posterior end unites with the basi-sphenoid in the middle line, and with the pterygoid laterally. In front of the basi-sphenoid it embraces, not a distinct presphenoid (as in *Pterobalæna*, according to Eschricht), but the inferior surfaces of the orbito-sphenoids, which are very thick; and, being applied together by their flat median faces, apparently replace the proper presphenoid.

Both these bones and the alisphenoids are small, and almost confined to the base of the skull.

The supra-occipital and inter-parietal are united together, and completely overlap and hide the parietals in the roof of the skull. The separate frontals only enter into the anterior wall of the skull, and between them and the orbito-sphenoids an oval aperture is left, doubtless diminished in the recent state by the ethmoidal cartilage. Laterally, the frontals are prolonged outwards and backwards into two great supra-orbital processes, which nearly meet the zygomatic processes of the squamosal. The short jugal bones, absent in the specimen figured, extend in the *Balænoidea* from the zygomatic process to the anterior and external angles of the supra-orbital prolongations, and are distinct from the lachrymals.

The pterygoids are completely separated by the palatines (Fig. 61). In front of the latter the maxillæ almost wholly exclude the premaxillaries from the palate, while they send great processes obliquely outwards and backwards, in front of the supra-orbital prolongations of the frontal. The long premaxillæ, on the other hand, pass upwards and backwards on each side of the elongated and symmetrical nasals to meet the frontals, and exclude the maxillæ altogether from the anterior nares.

The rami of the lower jaw are very narrow, and so much arched outwards as to be able to enclose the baleen plates attached to the upper jaw when the mouth is shut.

Eschricht has described, with much care, the changes which the skulls of the *Balænoidea* undergo in passing from the fœtal

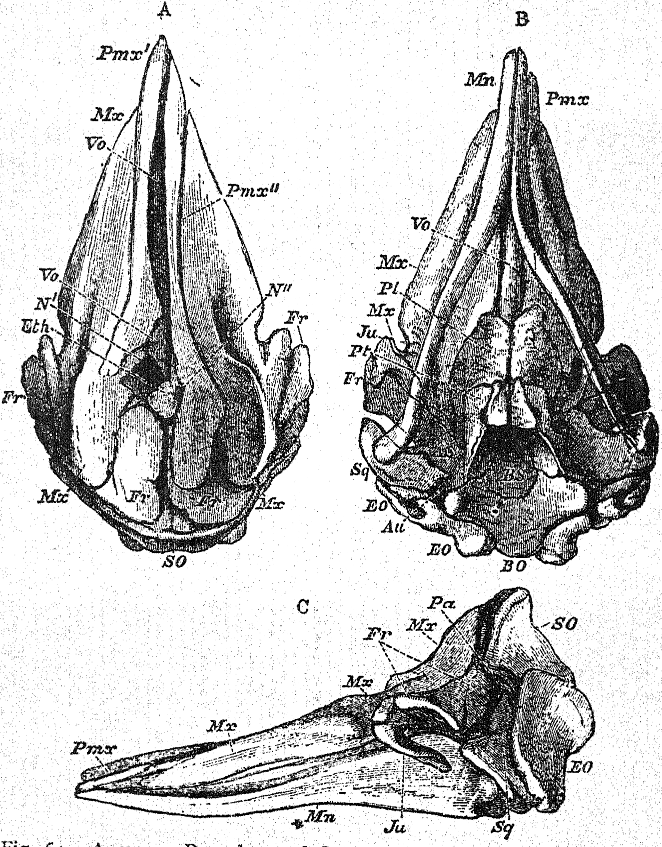


Fig. 64.—A, upper, B, under, and C, side views of the skull of a fœtal Cachalot in the Museum of the Royal College of Surgeons. The nasal bones are not represented in Fig. A.—N′ left, N″ right, nostril. The hinder extremity of the jugal, *Ju*, has fallen down from its natural connection with the zygomatic process of the squamosal.

to the adult condition, justly remarking that the skull of even a large fœtus is more different from that of the adult, than the

skulls of distinct species of the same genus of Whales are from one another.

The growth of the walls of the cranial cavity relatively to that of the external prolongations of the cranial bones and to that of the jaws, is soon arrested, and in addition the position and relations of some of the cranial bones become altered. In the smallest fœtuses of the lesser Fin-back (*Pterobalæna minor*), for example, the parietal region is occupied by the inter-parietal bone and the great fontanelle which lies in front of it. In larger fœtuses the fontanelle becomes closed by the progressive backward growth of the frontals, but the extension of the bones does not cease with their contact. The parietals grow over the inter-parietal and spread over it until they meet in the middle line. Hence the inter-parietal is eventually visible only in the interior of the skull. Anteriorly, the parietals grow over the frontals almost to the same level as the nasals, and thus conceal the share which the frontals take in the formation of the roof of the skull. But, at the same time, the supra-occipital extends from behind over the parietals; so that, at length, in that region which, in the youngest fœtus, was covered only by the inter-parietal, three bones—the inter-parietal, parietal, and supra-occipital—are superimposed.

The skulls of the other great division of the *Cetacea*, the *Delphinoidea*—or Dolphins, Porpoises, and Cachalots—are almost all distinguished by their very marked asymmetry.

In the Cachalot, or spermaceti Whale (*Physeter*), for example, the right premaxilla is much longer than the left, extending far back upon the right frontal, while the left does not reach the left frontal; the left nostril, on the other hand, is much more spacious than the right (Fig. 64, A). On the base of the skull (Fig. 64, B) the pterygoid bones unite in the middle line and prolong the palate, as in *Myrmecophaga* and *Ornithorhynchus*. When they and the palatine bones are removed, the axis of the lower part of the ethmoid is seen to continue that of the basi-cranial bones, which are, as usual, quite symmetrical. Superiorly, however, the ethmoidal plate is twisted over to the left side, and deeply grooved on the right side to form the inner wall of the small right nostril.

The vomer, which embraces the ethmoid and the presphenoid below, is also asymmetrical posteriorly, presenting a long and shallow lateral excavation, on the left side, and a short and deep one on the right. The maxillæ are correspondingly unsym-

metrical in the region of the nasal aperture, but elsewhere they are pretty nearly symmetrical. But it is the nasal bones which exhibit the greatest distortion, the left and right being very unequal in size and dissimilar in form.

The jugal and the lachrymal commonly become anchylosed.

The basi-occipital, as in the *Balænoidea*, gives off a lateral downward process, which unites, behind (Fig. 65), with an outward prolongation of the ex-occipital, and, in front, with the pterygoid, to constitute the inner wall of a deep chamber for the

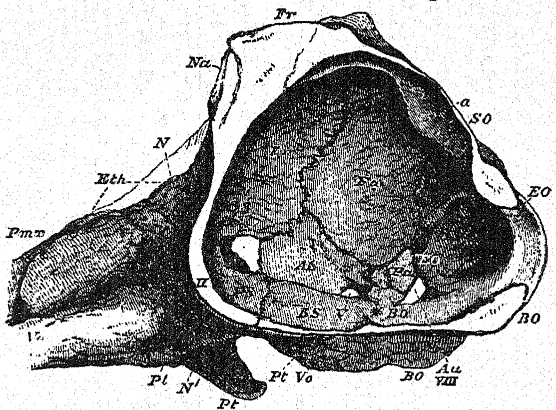


Fig. 65.—Longitudinal and vertical section of the skull of the White Whale or Beluga (*Delphinapterus*). * marks a distinct bony element interposed between the alisphenoid, the parietal, and basi-cranial axis; *a*, the ossified falx.

tympano-periotic. But the roof of this chamber is chiefly formed by the very large alisphenoid, which extends outwards to unite with the frontals, parietals, and squamosals, and backwards to the ex-occipitals. The aperture which is left between the hinder edge of the alisphenoid, the ex-occipital, basi-occipital and basi-sphenoid, is exceedingly small, so that the tympano-periotic is still more shut out from the cranial cavity than in *Balæna*. In *Hyperoodon* and *Orca* the aperture is still further reduced; but this peculiarity cannot be said to be a distinctive character of the Delphinoid skull, as in *Platanista* the aperture is large, and the periotic appears in the interior of the cranial cavity in the ordinary way.

VIII. THE THEORY OF THE VERTEBRATE SKULL

In the preceding Lectures I have, as far as possible, confined myself to a statement of matters of fact, and to the conclusions which immediately flow from the application of a very simple method of interpretation to the facts. That method of interpretation is based upon the principle that, in any two skulls, those parts which are identical in their principal relations in the adult state, and in the mode in which they reach this state (or in their development) are corresponding, or homologous, parts, and need to be denominated by the same terms.

By the application of this method it has been possible to demonstrate the existence of a fundamental unity of organisation in all vertebrate skulls; and, furthermore, to prove that all bony skulls, however much they may differ in appearance, are organised upon a common plan, no important bone existing in the highest vertebrate skull which is not recognisable in the lowest completely ossified cranium.

The enunciation of these results alone is a "Theory of the Skull," but it is by no means what is commonly understood as *the* theory of the skull.

For it will be observed that the statement just put forth confines itself to a simple generalisation of the observed facts of cranial structure, and would be perfectly complete were the skull a self-subsistent structure, devoid of any connection with a trunk. On the other hand, that doctrine to which the title of "The Theory of the Skull" is ordinarily applied, embraces not only such a generalised statement of the facts of cranial structure as this, but adds a hypothesis respecting the relations of the skull to the spinal column. It assumes that the bony cranium (the cartilaginous and membraneous states of the cranium it usually ignores) is composed of elements homologous with those which enter into the structure of the spinal column; that, in fact, it consists of modified vertebræ. And it is commonly conceived that it is the doctrine of the unity of structure of the skull and of the vertebral column, rather than the demonstration of the unity of organisation of skulls, which is one of the chief glories of morphology.

The assumption that every skull repeats the organisation of the trunk and consists of a certain number of modified vertebræ,

evidently implies a belief in the unity of organisation of skulls; but it is to be carefully noted that the converse proposition does not hold good; for it is quite possible to hold that all skulls are modifications of one fundamental plan, while wholly disbelieving that plan to be similar to the plan of a vertebral column.

Looking broadly at the history of the theory of the skull (using the phrase in its widest sense), I note three great lines of inquiry which have brought that theory into its present condition—the first originated by Oken and Goethe; the second, not originated, perhaps, but chiefly fostered and developed by Geoffroy St. Hilaire and Cuvier; the third, originated, and almost exclusively worked out, by Reichert, Rathke, and their followers among the embryologists of Germany and England.

I. I have united the names of Goethe and of Oken as the originators of the hypothesis of the vertebral structure of the skull, as a matter of equity, and to aid in redeeming a great name from undeserved obloquy; though, in strict technical justice, the claim of the one to priority lapsed through lack of publication.

Goethe combined with a fervid creative genius, which has placed him on a level with the greatest poets of all ages, so much of observational acuteness and of intellectual precision as might have sufficed for the equipment of a well-reputed man of science. From his youth up, passionately devoted to the natural sciences, more especially to botany and to osteology; and induced by the habit of his mind to search for the general truths which give life to the dry bones of detail, Goethe had been led to drink deeply of the spirit of morphology, during his study of the metamorphosis of plants and his successful search after the premaxillary bones of man, imagined, before his time, to be wanting. With a mind thus prepared, it was no wonder that, as Goethe writes, the notion of the vertebral composition of the skull had early dawned upon him:—

"The three hindermost parts I knew before, but it was only in 1791, on picking up an old and broken sheep's skull amidst the sandy dunes of the Jewish cemetery in Venice, that I perceived the facial bones also to be made up of great vertebræ; and observing, as I clearly did, the gradual passage from the first pterygoid bone to the ethmoid bone and to the spongy bones, the whole became plain."

Not improbably deterred, however, by the many difficulties

which must have presented themselves to him, in attempting to carry out these views with due scientific sobriety, Goethe kept them to himself, or shared them only with his immediate friends, for thirty years; the passage cited, in which they are first mentioned, bearing the date of 1820.

But, in 1807, Lorenz Oken independently originated and, what is more to the point, published those views of the vertebral composition of the skull which have since attained such world-wide celebrity; so that the great poet's silent partnership in the affair would be hardly worth mentioning were it not that his reticence has been made the ground of severe attacks upon his honour and veracity. It has been suggested that Goethe, full of years and of honours, thought it worth while to attempt to steal from the young Professor of Jena the fame that had accrued to him. And upon the infamy of such petty larceny the poet's latest accuser has heaped the insinuation that the author of "Faust" and of "Meister" was so stupid a plagiarist as to copy, not only Oken's views, but his account of the manner in which he came by them.

"Vaguely and strangely, however, as Oken had blended the idea with his *à priori* conception of the nature of the head, the chance of appropriating it seems to have overcome the moral sense—the least developed element in the spiritual nature—of Goethe, unless the poet deceived himself." [1]

"The circumstances under which the poet, in 1820, narrates having become inspired with the original idea are suspiciously analogous to those described by Oken in 1807, as producing the same effect on his mind." [2]

It would be difficult to couch an offensive accusation in stronger phraseology than this; but, by a singular chance, the scientific morality of its object has recently been fully vindicated. Goethe, when in Italy, kept up a correspondence with the family of his friend Herder. His letters have been published, and in one addressed to Madame Herder, and dated May 4, 1790, this passage occurs:—

"By the oddest, happy chance, my servant picked up a bit of an animal's skull in the Jews' Cemetery at Venice, and, by way of a joke, held it out to me as if he were offering me a Jew's skull. I have made a great step in the explanation of the formation of animals."

[1] "Encyclopædia Britannica," eighth edition, vol. xvi. p. 501; article, "Oken."
[2] *Ibid.*, p. 501.

Can it be doubted that this "great step" is exactly that vertebral theory of which Goethe says, writing in 1820, he had as clear a view "thirty years ago?" It is to be hoped that this evidence, which Professor Virchow has so strikingly put forward, will henceforward silence even the most virulent of Goethe's detractors, although a careful perusal of the arguments used by Mr. Lewes, in his "Life of Goethe," might have already sufficed those who were open to conviction.

The idea, which dropped still-born from Goethe's mind, was, as I have said, conceived afresh by Oken, and came vigorously into the world in that remarkable discourse (occupying in print about fourteen quarto pages) with which he inaugurated his professional labours at Jena.

It is hard to form a just judgment of this singular man; and, I must confess, I never read his works without thinking of the epithet of "inspired idiot," applied to our own Goldsmith: so strange is the mixture of insight and knowledge with what, to my apprehension, is mere "sound and fury, signifying nothing." But the "Programm" contains far more of the former and less of the latter ingredient than is usually noticeable in Oken's lucubrations, and it appears to me to be, at the present moment, by far the best specimen extant of the style of speculation about the skull, characteristic of the school which Oken originated. Indeed, if for the term "cranial vertebræ," "cranial segments" be substituted, I do not know that the plan of composition of the osseous brain-case can be better described than in the language which I shall now quote.[1]

The "Programm" opens thus:—

"A vesicle ossifies, and it is a vertebra. A vesicle elongates into a tube, becomes jointed, ossifies, and it is a vertebral column. The tube gives off (according to laws) blind lateral canals; they ossify, and it is a trunk skeleton. This skeleton repeats itself at the two poles, each pole repeats itself in the other, and they are head and pelvis. The skeleton is only a developed (*aufgewachsenes*), ramified, repeated, vertebra; and a vertebra is the preformed germ of the skeleton. The entire man is only a vertebra.

[1] "Ueber die Bedeutung der Schädelknochen. Ein Programm beim Antritt der Professur an der Gesammt-Universität bei Jena." Von Dr. Oken. Jena. 1807.

"I.

"Take a lamb's skull, separate from it those bones which are considered to be facial, and those bones of the cerebral capsule which take no share in the base, such as the frontal bones, the parietal bones, the ethmoid and the temporal bone, and there remains a bony column, which every anatomist will at once recognise to be three bodies of some sort of vertebræ, with their lateral processes and foramina. Replace the bones of the cerebral capsule, with the exception of the temporal bones (for the cavity is closed without these), and you have a vertebral column, which is distinguished from the true one only by its expanded spinal canal. As the brain is the spinal marrow more voluminously developed [in relation] to more powerful organs, so the brain-case is a more voluminous spinal column.

"If there are three vertebral bodies in the brain-case, there must be as many vertebral arches. These are to be sought out and demonstrated.

"You see the sphenoid separated into two vertebræ: through the first one pass the optic nerves, through the hinder the nerves of the jaws (*par trigeminum*). I term the former the *Eye vertebra*, the latter the *Jaw vertebra*. Against this last abuts the basilar process of the occipital bone with the petrous bone. The two form one whole. As the optic nerve traverses the Eye vertebra, and the jaw nerve the Jaw vertebra, so the hindermost vertebra is related to the auditory nerve. I therefore term it the *Ear vertebra*. Again, this is the first cephalic vertebra; the precedent, the second; and the eye vertebra, the third.

"It has given me unspeakable trouble to make out whether the petrous bone belongs to the first or to the second cephalic vertebra. Before I had taken into account the relations of the nerves, vessels, and muscles, my decision was based only upon the structure of the skulls of Birds, Lizards, and *Chelonia*; but now I have fortified it by a multitude of concurrent arguments, of which I will state only a few in this place.

"You will have observed, in fact, that each of the two anterior vertebræ has appropriated a sense. (As the jaws end in the lips, I reckon them also among the [organs of] sense, and I shall demonstrate that they are so, and how they are so.) Now, if the petrous bones belonged to the jaw vertebra, one vertebra would give off nerves to the sensory organs, while the first vertebra would be sent empty away. True, it transmits nerves

to the tongue, but these are variable; and it will be shown in the sequal that neither tongue nor nose have, or can have, a proper vertebra. Lastly, in Lizards, the auditory apparatus lies distinctly in the occipital bone.

"The cephalic vertebræ are, therefore, *sensory vertebræ*, and only exist in correspondence with the [cephalic] senses. (The tongue and the nose are trunk senses, of which presently.) Vertebral divisions and cephalic sensory nerves go parallel with one another. Bones are the earthly, hardened nervous system; nerves are the spiritual, soft, osseous system—*continens* and *contentum*.

"Between the sphenoid and occipital bones, between the sphenoid and petrous bones, between the parietals (the temporal bones are away) and the occipital bone, draw a line, and you have marked off the first vertebra. Draw another line between the two sphenoids, or, in Man, in front of the pterygoid processes; laterally, through the *fissura orbitalis* in front of the *alæ magnæ*; lastly, between the frontals and the parietals, and you have the second vertebra separated from the last.

"1. Now, take the ear vertebra of a fœtus of any Mammal or of a Man; place beside it an incompletely-developed dorsal vertebra, or the third cervical vertebra of a Crocodile, and compare the parts of which the two are composed—their forms, their contents, and the exits of the nerves.

"According to Albinus and all anatomists, each vertebra of a fœtus consists of three separate pieces—the body and the two arches, which together form the spinous, transverse, and oblique processes. You have the same in the occipital bone, only more distinct and separate. The *pars basilaris* is a *corpus vertebræ* still more separated from the condyloid parts, which form the lateral regions; these are again separated from the *pars occipitalis*, which forms the spinous process. In fact, this part itself is often split again, like the spinous processes in *spina bifida*. The occipital bone, therefore, is decomposable, according to the mode of its origin, into five pieces, since the lateral, or articular, and the spinous parts appear as independent developments; as is found also in actual vertebræ, which consist of five pieces, and in the third cervical vertebra of the Crocodile. Finally, I need take no further pains to prove that the occipital foramen is the lower aperture of a vertebral canal; that the *foramen lacerum* is an inter-vertebral foramen, and the occipital protuberance is a spinous process; that, therefore, the occipital

bone, in respect of form, as of function (since it encloses the cerebellum, as a continuation of the spinal marrow), is in every sense a true vertebra, since the mere naming of these parts is enough to cause their recognition as such.

"You will think I have forgotten the petrous bone. No! It seems not to belong to the vertebræ as such, but to be the sensory organ in which the vertebral—the auditory—nerve loses itself, and, therefore, to be an organ as completely separated from vertebral production as any other viscus, or as the ball of the eye; the deception lies only in this, that it is the essence of this organ to be ossified, as it is that of the eye to be crystalline.

"The mastoid process is, in animals, and also in the human fœtus, a proper bone, in which the styloid process lies. It is plainly inserted into the first vertebra, but it receives its signification from the tongue.

"2. Having entered so fully into the discussion of the first cephalic vertebra, I might, except for clearness' sake, spare you any delay over the second. But I will also demonstrate in this how completely the brain-case is formed according to the idea of a vertebra, and has even been partially produced as such.

"In every skull of a fœtus you may find the *alæ orbitales* of the sphenoid separate from it. They belong to the third vertebra. But, in the half-developed fœtus, the great wings and the pterygoid processes are also separate from the body of the sphenoid. The last-mentioned processes are foreign to the sphenoid, and only coalesced with it; they belong to quite another formation, and very probably have the same signification as the *os omoideum* of the Bird's head, as Cuvier has already indicated. I shall return to them.

"There remain, therefore, for the posterior sphenoid, or the jaw vertebra, three portions of bone—the body and the great wings, or the lateral and oblique processes of the vertebra. The spinous processes are formed by the two parietals, which, in many animals, coalesce so as to leave no suture, but are yet originally two. It is to be remarked that, in the Sheep, this vertebra is closed by the bones in question, without the intermediation of the temporal, which also does not belong to the vertebral group. The same occurs in the Chelonian, the Crocodile, etc.

"3. Whoso has recognised the second vertebra, as such, need only look at the third, especially in Ruminants, to discover quite the same structure. The anterior sphenoid with the

alæ orbitales represents the body, together with the lateral processes; the two frontals form the spinous process, together with its lateral parts.

"The sphenoid is separated into two vertebræ, not merely in the human fœtus and in Ruminants, but also in the Apes, in *Bradypus tridactylus, Dasypus novemcinctus*, Dog, Wolf, Bear, Otter, Rodents, and probably in all Mammals, if examined in a sufficiently young state. The law is therefore universal.

"The inter-vertebral foramina are very well marked between these vertebræ. A deviation seems to exist, on account of the foramina which lie in front of the first cephalic vertebra, namely, the *foramen caroticum* and *lacerum*, concerning which I must leave it undecided, whether they are originally two, or only one which has become separated. On this point evidence enough is to be found among animals. The organ of hearing has here interposed itself. On the other hand, it is characteristic of the cephalic vertebræ that their sides are perforated by nerves—by the optic nerve, the jaw nerves, and the hypoglossus, if we reckon the auditory and facial nerves as inter-vertebral nerves: a circumstance which demands further inquiry.

"So much of the cephalic vertebral column. I might have been able to treat more fully and thoroughly of it, and to have indicated the nerves, veins, and muscles, which in the head correspond to those of the trunk, and the like for the bones; but in a programme one must be content with merely putting forth one's view of a question.

"II.

"If the cerebral capsule is the repetition of the spinal column, only more expanded and organised (I speak as an anatomist), the head must repeat the outgrowths of the spinal column, the thorax, the pelvis, and the limbs; and, indeed, thereby must it attain completeness.

"By this union of the representatives of all the bones of the trunk arises the wonderful, but yet analysable, mixture and intercurrence of formations which appear as the facial bones. The spinal column becomes the brain-case; the walls of the trunk, with the extremities, become the face."

In developing this idea, Oken arrives at the conclusion that the nasal cavity is the thorax of the head, and the oral cavity the abdomen of the head. The squamosal is the conjoined scapula and ilium of the head; the pterygoid, the clavicle; the

hyoidean apparatus, the other pelvic bones. The jugal arch represents the humerus, radius, and ulna; the maxilla, the hand; the premaxilla, the thumb; the teeth, the fingers. The lower jaw represents the legs of the head; the teeth the toes; and, of all imaginable hypotheses, the styloid processes are the sacrum of the head!

Reasons, worthy of the name, for these identifications are not to be found in the "Programm." Oken, having assumed once for all, that, as the brain-case repeats the spinal canal, the facial bones must repeat the other appendages of a vertebral column and the limbs, seems to have troubled himself no further about demonstration. What a bone should be, in order to fit plausibly into his scheme, that it was at once settled to be—an appeal to the "idea" dispersing all doubts.

A few years later Oken modified his original conception so far as to regard the nasal apparatus as a fourth vertebra.

Whatever may be thought about the more speculative passages of the extract above cited from Oken's work, and of his *à priori* conception of what a skull must be, it contains ample evidence that he did, *à posteriori* and inductively, demonstrate the segmented character of the bony brain-case; and had nothing more ever been written on the subject, this great truth would have remained as a splendid contribution to morphology. But Oken greatly amplified the observational basis of his own doctrine; Spix took it up, in a modified form, and worked it out, in his own way, through the series of the *Vertebrata* in his great illustrated "Cephalogenesis," published in 1815; Bojanus did the like in the pages of the "Isis," and in the "Parergon" of his splendid monograph, the "Anatome Testudinis"; and, finally, C. G. Carus developed the doctrine, as far as it could well go, both *à priori* and *à posteriori*, in his "Urtheilen des Knochen und Schälen-Gerustes," published in 1828; in which, under the names of "Grund-form" and "Schema," we have, among other things, "archetypal" diagrams of the *Vertebrata* generally, and of each vertebrate class.

Under these circumstances, the following passage, extracted from the article in the "Encyclopædia Britannica" already cited (*supra*, p. 274), may not improbably excite in other minds as much astonishment as it has in mine:—

"As to the question of the superiority of the deductive over the inductive method of philosophy, as illustrated by the writings of Oken, his bold axiom that heat is but a mode of motion of

light, and the idea broached in his essay on 'Generation' (1805), viz., that 'all the parts of higher animals are made up of an aggregate of *Infusoria*, or aggregated globular Monads,' are both of the same order as his proposition of the head being a repetition of the trunk, with its vertebræ and limbs. Science would have profited no more from the one idea without the subsequent experimental discoveries of Oersted and Faraday, or by the other, without the microscopical observations of Brown, Schleiden, and Schwann, than from the third notion, without the inductive demonstration of the segmental constitution of the skull by Owen. It is questionable, indeed, whether in either case the discoverers of the true theories were excited to their labours, or in any way influenced, by the *à priori* guesses of Oken; more probable is it that the requisite researches and genuine deductions therefrom were the results of the correlated fitness of the stage of the science, and the gifts of its true cultivators at such particular stage."—P. 502.

Thus does the moralist upon Goethe's supposed delinquencies think it just to depreciate the merits of Oken, and exalt his own, in the year 1858. But if he himself had not been "in any way influenced" by Oken, and if the "Programm" is a mere mass of "*à priori* guesses," how comes it that only three years before Mr. Owen could write thus? [1]

"Oken, ce génie profond et pénétrant, fut le premier qui entrevit la vérité, guidé par l'heureuse idée de l'arrangement des os crâniens en segments, comme ceux du rachis, appelés vertèbres."

And, after sundry extracts from Oken's "Programm," could continue:—

"Ceci servira pour exemple d'un examen scrupuleux des faits, d'une appréciation philosophique de leurs rélations et analogies, en un mot de l'esprit dans lequel Oken détermine les rélations vertébrales des os du crâne."—P. 158.

And again:—

"Quand on commença à apprécier la vérité de la généralisation d'Oken, on se rappela, comme c'est l'habitude, que quelqu'un avait eu un idée à peu près semblable. . . . Mais toutes ces anticipations ne sauraient enlever à Oken le mérite de la première proposition definie d'une théorie."—P. 161.

The space at present occupied by the proclamation of the

[1] "Principes d'Ostéologie comparée, ou Recherches sur l'Archétype et les Homologies du Squelette vertébré."—P. 155. 1855.

weakness of the "moral sense" of Goethe may not unfitly be taken up, in the next edition of the "Encyclopædia Britannica," by the extrication of the author of the article "Oken" from the singular dilemma in which these citations place him.

The fact is, that, so far from not having been "in any way influenced" by Oken, Professor Owen's own contributions to this question are the merest Okenism, *remanié*. In the work I have cited, not a single fact, nor a single argument, can be found by which the doctrine of the segmentation of the skull is placed on a firmer foundation than that built by Oken. Two novel speculations are indeed brought forward, the one of which confuses the petrosal (in the Cuvierian sense) of the lower *Vertebrata* with the homologue of the alisphenoid of Man, and, consequently, would, if adopted, throw the whole subject into hopeless chaos; while the other — the supposition that the fore limb is an appendage of the head—can only be explained by that entire want of any acquaintance with, or appreciation of the value of, embryology which all the writings of the same author display.

II. The great works of Spix and Bojanus contain, apart from the theory which they attempted to establish, abundant evidence of the unity of composition of the bony skull, but it was Geoffroy St. Hilaire and, more especially, Cuvier, who demonstrated that unity of organisation, apart from all hypotheses, most thoroughly and completely. The fresher one's study of the writings of the wilder Okenians—the more one has become weary of wading through empty speculations upon "connation" and "coalescence," "irrelative repetition" and "transposition," the *Dei ex machinâ* who are called in to solve every difficulty—the more heartily does one sympathise with the sarcastic vigour with which Cuvier annihilates the products of their exuberant fancy in the notes to the "Ossemens Fossiles," and the "Histoire Naturelle des Poissons." Nor is it possible to peruse without admiration the sagacious reasonings by which he was led to determinations which, in the majority of cases, have been accepted by those who have followed him.

Meckel Köstlin, in his elaborate and valuable special work on the Vertebrate Skull, and Hallmann, in his excellent essay on the Temporal Bone, have built on Cuvier's foundations, applying further and, in some cases, bettering, his determinations of the homologues of particular bones. No one can study these works carefully and retain a doubt that osseous skulls are con-

structed upon a uniform plan, though he may, with Cuvier, give but a hesitating and grudging assent to the notion that it is, in some sense, a modified vertebral column.

III. That criterion of the truth or falsehood of the vertebral theory of the skull, for which the Okenians do not think it necessary to look, and which Cuvier seems to have sought in vain, has been furnished by the investigations of the embryologists from the year 1837 to the present time.

The first step was the discovery of the visceral arches by Reichert; the second, the demonstration of the mode of development of the skull, in all classes of the *Vertebrata*, by the remarkable researches of Rathke, contained in the "Vierter Bericht über das Naturwissenschaftliche Seminär bei der Universität zu Königsberg," which was published in 1839. I will quote Rathke's statement of his conclusions at length, so that we may have the means of fairly comparing his mode of going to work with that of Oken:—

"The following results, among others, are deducible from the observations which have been detailed:—

"(1.) At the earliest period of fœtal life the notochord extends backwards, as far as the end of the body; forwards, only to the interspace between the auditory capsules.

"(2.) The gelatinous investing mass, which, at first, seems only to constitute a band to the right and to the left of the notochord, forms around it, in the further course of development, a sheath, which ends in a point posteriorly. Anteriorly, it sends out two processes which underlie the lateral parts of the skull, but very soon coalesce for a longer or shorter distance. Posteriorly, the sheath[1] projects but little beyond the notochord; but, anteriorly, for a considerable distance, as far as the infundibulum. It sends upwards two plates, which embrace the future central parts of the nervous system laterally, probably throughout their entire length.

"(3.) The investing mass of the notochord is the material out of which the vertebral column and a great part of the skull, though not the whole skull, are developed.

"(4.) The most essential part of a vertebra is its body. With the exception of a few cartilaginous fishes, the cartilaginous foundation of that body (the notochord having disappeared earlier or later), has the form of either a ring, or a half ring; or, as is the case among the *Mammalia*, forms a solid mass,

[1] Perhaps with rare exceptions, as in *Fistularia tabaccaria.*

having the form of the segment of a cylinder. Subordinate parts of the vertebra are the vertebral arches and transverse processes, together with the ribs, which all, at the time they take on a cartilaginous character, appear as rays of the body, though sometimes they are not developed at all. Only in rare cases (*Petromyzon*) are vertebral arches developed without vertebral bodies; that part of the investing mass of the notochord which is, in other cases, applied to the formation of such bodies, acquiring only a membraneous consistency.

"(5.) From that part of the investing mass of the cephalic part of the notochord, which consists of the anterior part of the sheath of the notochord and its anterior paired processes, are developed the basi-occipital, the basi-sphenoid, and the ethmoid, so that the ethmoid is the most anterior of the parts of the skeleton which take their origin from the investing mass of the notochord. The basi-occipital is formed in that part of this mass which surrounds the cephalic part of the notochord like a sheath; the basi-sphenoid, in that part of it which lies between the paired processes (the *trabeculæ*) and the anterior end of the notochord; and the ethmoid (more particularly its body, or *pars perpendicularis*), in the anterior coalesced part of those two processes. The body of the presphenoid, on the other hand, is formed below the processes in question, rarely between them.

"(6.) The parts of the skull just mentioned, however, do not ossify in all *Vertebrata* with an osseous skeleton, but one, or several, of them sometimes remain cartilaginous, and then grow relatively far less than the others, so that they seem to be pushed aside and suppressed by the neighbouring bones. This holds good especially of the basi-occipital of the *Batrachia*, and of the basi-sphenoid of these animals and of osseous Fishes.

"(7.) The basi-occipital (or, at least, the substance out of which it will become developed) constitutes, originally, like the body of a vertebra, a sheath round a part of the notochord, and the ex-occipitals appear, whilst they chondrify, as outgrowths from the basi-occipital part; just as the arches of a vertebra, when this is normally developed, appear as outgrowths from its already chondrified body. For the rest, however, the normal development of the occipital bone is quite similar to that of a vertebra, and it therefore may with perfect justice be held to be a cephalic vertebra. The *squama occipitis*, which occurs in

[1] The *Foramina condyloidea*, which occur in the ex-occipitals of many *Vertebrata*, remind one of the holes of the vertebral arches of the Sharks.

many, but not in all *Vertebrata*, and which is not always placed between, but sometimes lies in front of the ex-occipitals, presents no difficulty in the way of this interpretation; it is an accessory structure, a so-called intercalary bone, the presence of which depends upon the excessive development of the brain.

"(8.) The two rings, on the other hand, which are formed by the two sphenoids, with the parietals and frontals as their intercalary bones, are no longer constructed upon quite the same type as the vertebra. That the alisphenoids and orbito-sphenoids, when they are already chondrified, do not appear to take the form of outgrowths of their centres, but are united with them by membrane, need not, perhaps, be taken very much into account, since, in the Lampreys, the arches of the vertebræ arise independently within the lamellæ, which the investing mass of the notochord has sent out to embrace the central parts of the nervous system. Still less weight can be attached to the circumstance that not unusually, even when both sphenoidal centra are present, only one pair of the corresponding alæ appears; while, in other cases, two pair of alæ and only one central part are present, since the caudal vertebræ of *Mammalia* usually exhibit no traces of arches, and the Lampreys have such arches without centra. On the other hand, the circumstance is important that the basi-sphenoid, although it arises within the investing mass of the notochord, is not developed around this (as, so far as our present observations go, even the most posterior caudal vertebræ are), but in front of it, in a process of the investing mass; and that the body of the presphenoid is no longer developed, even in a part of this mass (except in a few *Mammalia*), but arises quite independently of it. Hence, the two sphenoids no longer agree perfectly with vertebræ in their development—the anterior diverging more widely from the vertebral type than the posterior.

"(9.) Yet the two sphenoids, like the proper vertebræ, still embrace segments of the nervous tube (such as is formed by the brain and spinal marrow, at any rate in the early stages of development), and they constitute, as the vertebræ at first normally do, open rings, or rather segments of rings, round that tube. The ethmoid, however, at no time surrounds a segment of the nervous tube in question; but, in a few animals only, imperfectly includes, by its hinder part, two anterior prolongations of that tube, whence the olfactory nerves arise. Its mode of development, and its ultimate form likewise, are of such a

character that it no longer offers any special resemblance to a typically-formed vertebra. Nevertheless, considering that it arises from a part of the prolonged investing mass of the notochord—viz., from the anterior, early-coalescing parts of the two *trabeculæ*—and that its body (the *pars perpendicularis*) presents even a certain resemblance to the last caudal vertebræ of many Birds and osseous Fishes, it may well be considered to be a modified vertebra. We may look at it, in short, as the representative of only the body of a vertebra — such as normally each caudal vertebra of a Mammal is; and that from this, for the purpose of investing the olfactory apparatuses, which are developed at its sides, lamellar processes grow out, which are altogether peculiar to it. In any case, however, the ethmoid may be regarded as the anterior end of the vertebral column.

"(10.) From what has been stated, it appears that the four different groups of bones—the occipital, with its intercalary bone, the *squama*; the basi-sphenoid, with its intercalary bones, the parietals; the presphenoid, with its intercalary bones, the frontals; and the ethmoid, together with its outgrowths, the spongy bones and the cribriform plate—exhibit in their successive order from behind forwards, a greater and greater deviation from the plan according to which ordinary vertebræ are developed so that the occipital bone is most like a vertebra, while the ethmoid is least like one.

"(11.) Among the bones of the face, the premaxillæ, the nasal bones, and the vomer are developed altogether independently of the investing mass of the notochord; and they never coalesce with parts of the skeleton, which are immediately derived from the latter. On this account, alone, they cannot be regarded as vertebræ, or parts of vertebræ. Furthermore, they at no time enclose, or help to enclose, a segment of the central nervous system. The nasal bones and the vomer are, properly speaking, 'splint-bones' (*Belegungsknochen*) for the ethmoid, such as occur in the vertebræ of no animal; and the premaxillæ are applied, although in a different plane, to the one end of the vertebral column, as, in Fishes, the median rays of the anal fin are applied to the other end of it.[1] Furthermore, the palatine bones are developed, together with the pterygoids, in lateral processes, or rays, which have grown out from the middle part of the base

[1] The study of the development of the skull necessitates the assumption that Sturgeons, Sharks, and Rays have no premaxillæ, and that their skulls end anteriorly with the ethmoid cartilage.

of the brain-capsule, and which, as regards their original form, disposition, and connections, resemble the ribs, and may be regarded as a pair of ribs united with the brain-case. In *Mammalia* the two mallei are developed in these two rays, and perhaps the quadrate bones of many other *Vertebrata* in a part of them. Around them, however, is developed, in animals provided with an osseous skeleton, a coating of bony plates, which becomes metamorphosed into the lower jaw.

"At the outer side of those parts, moreover, in which the pterygoid and palatine bones arise—or, in other words, alongside the processes of the 'rays'—a substance arises, whence the upper maxilla and the malar bone are developed.

"The upper maxilla and malar bone therefore might be regarded, like the lower maxilla, as splint bones or rib-like bones (which, however, do not occur in connection with true ribs), but not as parts of the vertebra itself.[1] The lachrymal bone, lastly, only fills up a gap between other bones of the face, and therefore, if analogies must be discovered, can only be regarded as an intercalary bone.

"(12.) The auditory capsules and the petrosal bones, which are developed out of them in many animals, may, in respect of their place and origin, be most fittingly compared with those intercalary bones which occur in Sharks and Sturgeons, between the arches of the vertebræ; but, in respect of their form, take a different course from these. And since those intercalary pieces can hardly be considered to be parts of vertebræ, the auditory capsules cannot be regarded as such."

Vogt and Agassiz, resting upon embryological observations which entirely confirmed those of Rathke, carry out the argument suggested by the latter more rigorously.

"It has therefore become my distinct persuasion (says Vogt) that the occipital vertebra is indeed a true vertebra, but that everything which lies before it is not fashioned upon the vertebrate type at all, and that all efforts to interpret it in such a way are vain; that therefore, if we except that vertebra (occipital) which ends the spinal column anteriorly, there are no cranial vertebræ at all."[2]

[1] In the *Chelonia* and a few *Mammalia* bony elements occur, which cover the ribs and, in the first-mentioned animals, even become united with the ribs; they are developed, however, in the integument, and belong to the integumentary skeleton, and not to the nervous skeleton, so that they need not be considered here.

[2] "Entwickelungs-Geschichte der Geburtshelfer Krote."—p. 100. 1842.

But the further investigations of embryologists have demonstrated that the occipital segment of the skull is, developmentally, as different from a vertebra as all the rest, seeing that, as Remak has more fully proved than any other observer, the segmentation into "urwirbel," or proto-vertebræ, which is characteristic of the vertebral column, stops at the occipital margin of the skull—the base of which, before ossification, presents no trace of that segmentation which occurs throughout the vertebral column. By this third great step the vertebral hypothesis of the skull seems to me to be altogether abolished; even though Professor Goodsir, whose thorough acquaintance with embryology gives his opinions on these subjects great weight, has endeavoured, in his learned and ingenious essays, to combine the facts of development with that hypothesis.

IV. A fourth line of investigation, not bearing so directly upon the vertebral hypothesis, but still of great moment, was opened up by the observations of Arendt on the persistent cartilaginous cranium of the Pike,[1] and by the subsequent investigations of Von Bär, of Dugés, of Reichert, of Agassiz, of Jacobson, Sharpey, Spöndli, and Kölliker, and all the discussions which have taken place on the "primordial cranium" question. The problems attempted to be solved by these inquiries are—Is there a clear line of demarcation between membrane bones and cartilage bones? Are certain bones always developed primarily from cartilage, while certain others as constantly originate in membrane? And further, if a membrane bone is found in the position ordinarily occupied by a cartilage bone, is it to be regarded merely as the analogue, and not as the homologue, of the latter? In other words, is histological development as complete a test of homology as morphological development?

At present the course of investigation appears to me to tend towards giving an affirmative answer to these questions; but much and careful observation is yet needed.

Having concluded this rapid historical sketch of the gradual growth of the true theory of the skull, it may be well if I state, in a brief summary, what I conceive to be the present condition of our knowledge respecting its structure and development:—

[1] "De Capitis Ossei Esocis Lucii Structura Singulari." 1822. Nesbitt, however, appears to have been the first to direct attention to the difference between membrane bones and cartilage bones.

1. All crania result from the modification of the anterior part of that "primitive groove" of the embryo, the posterior part of which gives rise to the vertebral column; and, at the very first, there is no discernible difference between that part of the groove which will give rise to the vertebral column, and that from which the skull will be produced.

2. The first changes which take place, in both the cranial and the spinal regions of the primitive groove, are also precisely similar, the dorsal laminæ growing up and uniting together in the middle line, so as to enclose a cavity which is, on the one hand, the primordial brain-case, and, on the other, the primordial spinal canal. So far, a unity of organisation may be predicated of both brain-case and spinal canal; but the brain-case is not yet a skull, nor the spinal canal a vertebral column.

3. Beyond this point, the course of development of the cranial region differs absolutely from that of the spinal region. In the latter, that histological differentiation takes place which results in the formation of the proto-vertebræ, while in the skull no such process occurs. Again, the notochord extends throughout the whole length of the spinal column; while, as soon as the skull is distinguishable, as such, the notochord ceases to extend beyond the middle of its floor, stopping immediately behind that part which lodges the pituitary fossa.[1]

4. Furthermore, when chondrification takes place in the spinal column, separate masses of cartilage are developed in each proto-vertebra; but, when chondrification commences in the base of the skull, it gives rise to a continuous body of cartilage, which never exhibits any trace of transverse division, or segmentation; but is always divided under the pituitary body into two longitudinally-arranged crura, the "*trabeculæ cranii*."

5. Hence it follows that, though the primordial brain-case and the primordial spinal canal are identical in general plan of construction, the two begin to diverge as soon as the one puts on the special characters of a skull, and the other those of a vertebral column; the latter taking one road, while the skull takes another. The skull is no more a modified vertebral column than the vertebral column is a modified skull; but the two are essentially separate and distinct modifications of one and the same structure, the primitive groove.

6. The skull, having assumed its special and distinctive char-

[1] *Amphioxus* forms an exception, probably only apparent, to this generalisation.

acters, may pass through three successive states—the membraneous, the cartilaginous, and the osseous—in the course of its development; and the order in which these states succeed one another is always the same, so that the osseous skull has a cartilaginous, and the cartilaginous, a membraneous, predecessor. Nor does any one of these states ever completely obliterate its predecessor; more or less cartilage and membrane entering into the composition of the most completely ossified skull, and more or less membrane being discoverable in the most completely chondrified skull.

7. The adult skull may, however, have got no further than one of these states. In the *Amphioxus*, the skull (if skull it can be called) is membraneous. In many Fishes, as we have seen, it is cartilaginous, with, at most, a superficial conversion into bone. In the rest of the *Vertebrata* definite bones are added, to the more or less complete exclusion of the cartilaginous cranium.

8. When definite cranial bones are developed, they arise in one of two ways, either in the substance of the cartilaginous cranium, as "cartilage bones," or in the perichondrium, or remains of the membraneous cranium, as "membrane bones." It is highly probable that, throughout the vertebrate series, certain bones are always, in origin, cartilage bones, while certain others are always, in origin, membrane bones.

9. With the exception of *Amphioxus*, three sets of sensory organs—olfactory, optic, and auditory—are evolved in the walls of the skull of every vertebrate animal, and they are disposed, from before backwards, in the order in which they are named. All these sensory organs are originally developed in connection with involutions of the integument, which, in the case of the olfactory organ, remain open, but, in that of the eye and ear, become shut. Each sensory apparatus is, throughout the Vertebrate series, related to the same nerves: the olfactory being supplied by the first pair; the optic, by the second; the auditory, by the *portio mollis* of the seventh; while the fifth pair leaves the skull in front of the auditory capsule, and the eighth pair behind it. These relations of the cranial nerves to the sensory organs, and consequently to the cranial walls, are established antecedently to chondrification, and *à fortiori* to ossification; so that the cranial nerves and the sensory organs serve as fixed points by which the nature of the various ossifications can be determined.

10. By the help of these landmarks, chiefly, it has been possible to identify the bones known as basi-occipital, ex-occipitals, supra-occipital; basi-sphenoid, alisphenoids, parietals; presphenoid, orbito-sphenoids, frontals; or, in other words, the constituents of the walls of the brain-case, throughout the whole series—from the Pike to Man. And it is found that these bones, when they all occur together, are so disposed as to form three, originally distinct, segments.

11. Recourse to long-established, but frequently-forgotten facts in the history of the development of the so-called "*pars petrosa*," and "*pars mastoidea*," or periotic bone, of the human skull, has shown that these parts ossify from three centres, which have hitherto received no names, and which I have termed the "pro-otic," "opisthotic," and "epiotic" bones. It has been one of the principal objects I have had in view to prove, by paying careful attention to the relations of these osseous elements, on the one hand to the nerves, and on the other to the parts of the auditory organ which they enclose, that they are very generally represented, sometimes in a distinct form, and sometimes coalesced with one another, or with other bones, throughout the series of skulls provided with cartilage bones; and that the pro-otic, especially, is one of the most constant and easily-identifiable bones throughout the series of vertebrate skulls.

12. The eye is not invested by any cartilaginous or osseous elements of the cranial wall; but the olfactory sacs become more or less enclosed in a capsule, formed partly by a median cartilaginous plate, which results from the coalescence and out-growth, beyond the boundaries of the brain-case, of the *trabeculæ cranii*; partly, by outgrowths from the superior and inferior edges of that plate; and partly, by a prolongation outwards of the front part of the outer wall of the brain-case, into an antorbital process, between the orbit and the nasal sac, on each side. Cartilage bone developed in the septum gives rise to the ethmoid; in the antorbital processes, to the prefrontals; in the superior, or inferior, lateral prolongations of the side walls, to the turbinal bones. Membrane bones developed upon the roof of these olfactory capsules give rise to nasals; beneath the septum, to vomers.

13. The ethmoid and its dependencies are developed within the median "fronto-nasal" process, which grows out from the front wall of the embryonic skull, between the rudimentary

nasal sacs; and the inferior, broad, free edge of which bounds the mouth. It is in this free edge that the premaxillæ are developed, and they are, at first, perfectly distinct from the maxillæ. The latter, together with the palatine and pterygoid bones, are formed within the maxillary processes, which bound the sides of the primitive oral cavity, and run, parallel with one another, along the base of the fore-part of the embryonic cranium, uniting, behind, with the first visceral arch, but being, at first, completely separated, anteriorly, from the fronto-nasal process. Clearly therefore, if the premaxillæ and maxillæ, etc., are to be regarded as constituents of inferior arches of the skull, they are not parts of one arch, but of, at least, two distinct arches.

14. Of the first and second visceral arches, which lie immediately behind the mouth, the former, which gives rise to the mandible and quadrate bone, passes into the skull under the front part of the auditory capsule; while the root of the latter, in which a greater or smaller part of the hyoidean apparatus is developed, underlies the hinder part of that capsule. It is therefore impossible that the mandibular and hyoidean arches should be dependencies of any other parts of the skull than those which lie immediately in front of, or behind, the auditory capsules; and in the completely ossified skull we never, as a matter of fact, meet with these arches in any other position.

15. There is not a shadow of evidence that the mandibular and hyoidean arches suffer any shifting of position from before backwards, in the course of their development; but the extremities of those arches which are attached to the skull undergo very singular metamorphoses, the effect of which is, that the dentary part of the mandible is brought into closer connection with the skull the higher we ascend in the Vertebrate series. Thus, in the Fish it is separated from the skull by the hyomandibular, quadrate, and articular bones; in the Reptile by the quadrate and articular; while in the Mammal the quadrate and the articular are metamorphosed into the incus and the malleus, and the dentary comes close to the skull, articulating with the squamosal.

These are, I believe, the most important facts regarding the structure and development of the skull, which may now be regarded as well established. If we inquire how they bear upon theories of the skull, it will be obvious that they place the doctrine of the unity of organisation of the vertebrate skull

upon a perfectly sure and stable footing, while they appear to me, as clearly, to negative the hypothesis that the skull is, in any sense, a modification of vertebræ.

But though the skull has not a vertebral structure, and in its membraneous and cartilaginous states is not even segmented, it assumes a very definite segmentation in its completely ossified state.

In every well-ossified cranium there is, assuredly, an *occipital segment* (" Ear Vertebra " of Oken), formed by the basi-occipital, ex-occipitals, and supra-occipital; a *parietal segment* (" Jaw vertebra " of Oken), constituted by the basi-sphenoid, ali-sphenoid, and parietals; a *frontal segment* (" Eye Vertebra " of Oken), composed of the presphenoid, orbito-sphenoids, and frontals; and a *nasal segment* (" Nasal Vertebra " of Oken), formed by the ethmoid, prefrontals, turbinals, nasals, and vomer.

Leave out the hypothetical considerations that these segments are equivalent to one another, and that they are homologous with vertebræ, and Oken's expression of the broad facts of the structure of the completely ossified brain-case is, I believe, the best that has yet been given. Nay, we may go further with him, and look on the periotic bones as no part of the proper cranial wall, but as special developments within the otic capsule. But here we must stop, for neither anatomy nor development are reconcilable with the notions of the Okenian school respecting the limbs of the head. Carus suggested, from the Okenian point of view, that the premaxillæ and maxillæ must be cephalic ribs, and not cephalic limbs; but Rathke was the first to demonstrate that the inferior arches of the skull must be considered, if they are homologous with anything in the trunk, to partake of the nature of ribs rather than of that of limbs. But the confusion between analogy and affinity has led to such grave errors in the interpretation of the upper arches of the skull, that we must be upon our guard against running into similar mistakes with respect to the lower arches.

It is easy enough to enumerate four inferior arches to the skull, just as there are four superior arches—the premaxillæ forming the first of these arches; the palato-pterygoid and maxillary apparatus, the second; the mandible, with its suspensorium, the third; the hyoidean arch, the fourth: and it might be plausibly enough represented that the first of these is united with the nasal segment of the skull, the second with the frontal segment; while the third and fourth, being connected

respectively with the anterior and the posterior parts of the periotic capsule, might be fairly considered to belong to the parietal and occipital segments.

But do they really belong to those segments? and if so, why do they not remain attached to them? What relation have the branchial arches to the skull, again? It is hard to see in what morphological character the first branchial arch of a fish differs from its hyoidean arch; and if so, is it an arch of the skull, or an arch of the vertebral column? What, furthermore, are the original connections of the palato-pterygoid arch? Does it grow out of the mandibular arch from behind forwards, as Rathke seems to think; or has it, primitively, that connection with the prefrontal region which is so constant a character of the palatine bone?

These questions must be answered before the theory of the lower arches of the skull can be placed upon as satisfactory a footing as that of the upper arches; and they can be answered only by the embryologist, who may be encouraged to the difficult task by reflecting on what he has done already; though keeping in view the adage of the Roman, and

"Nil actum reputans si quid superesset agendum."

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